Appendix G

DETAILED LISTING OF ASSUMPTIONS, LIMITATIONS, AND ERRORS

This section contains a detailed list of assumptions, limitations, and known errors of TRAP 3.1a by Functional Area and Element. This information helps a user determine if the model adequately addresses all the phenomena and environmental conditions that are important to the intended application.

These assumptions, limitations, and errors were derived from any and all applicable sources, the primary source being the TRAP 3.1 Software User's Manual (SUM). Some assumptions, limitations, and errors were described in various locations in the main body of the SUM, while others were extracted from the detailed code descriptions in the appendices. Changes to the code were made after the TRAP 3.1 SUM was published, resulting in the release of TRAP 3.1a. A comparison of the 3.1a code to the 3.1 code was performed, and the assumptions, limitations, and errors identified in TRAP 3.1 were modified to reflect the code changes. Reports that have been generated during the development of TRAP 4.0, due in 1998, were also reviewed. Where possible, notes have been included to identify the impact of anticipated modifications on assumptions, limitations, or errors.

In some instances, the same assumption, limitation, or error may be present under different FEs. Repeating the entry in each location of the FAT where it applies allows the user to search quickly for all the information in their area of interest. References are listed, where possible. The following notation is used for SUM references: SUM page 6-4 refers to page 6-4 of the main body of the SUM; SUM, Appendix E, AEROPM-3, block (7) refers to block (7) on page 3 of the subroutine AEROPM in Appendix E. Where the information was taken from a source that is not reproducible, a full explanation of the assumption, limitation, or error is included, along with a reference to the TRAP 3.1 SUM that indicates the portion of the source code to which the description applies. The information in this section was compiled by Battelle.

ASSUMPTIONS

This section contains brief descriptions of the assumptions that have been identified in TRAP 3.1a. This section addresses the known assumptions identified in published sources or reported by model users and model developers. Other assumptions may become apparent during subsequent phases of the model accreditation process.

The contents of this section are closely linked with the following section on limitations. Indeed, many of the assumptions imply some limitation on the use of the model. In such cases, the limitation is indicated here under the heading of "Implications for Model Use", and, in general, the limitation has not been repeated in the following section. The assumptions are listed by FE number.

I TARGET CHARACTERISTICS

1.1 Configuration

1.1.1 Mass Properties

Assumption #1: For the non-generic target, only the mass is modeled. The target is assumed to have a constant center-of-gravity location.

Documentation Reference: SUM page 6-5.

Implications For Model Use: Does not support detailed modeling of target aircraft airframe dynamics.

Assumption #2: For the non-generic target, no moments-of-inertia are modeled (although the effects of the moments-of-inertia are implicitly included in the model of the pitch and roll dynamics, see 5.1.1.2.5).

Documentation Reference: SUM page 6-5.

Implications For Model Use: Does not support detailed modeling of target aircraft airframe dynamics.

Assumption #3: No mass properties are modeled for the generic target aircraft (the required accelerations are generated directly).

Documentation Reference: SUM page 6-5.

Implications For Model Use: Does not support detailed modeling of target aircraft airframe dynamics.

1.2 Target Movement

Assumption #1: If the initial speed is input as zero, then the initial Mach number is used to set the initial speed. If the initial Mach number has been input as zero, then the initial speed is used to set the initial Mach number. If both the initial speed and Mach number are input as non-zero quantities, whichever is read last from the data file will be retained and used to set the other.

Documentation Reference: SUM, Appendix E, TGINIT-12, block (4).

Implications For Model Use: User must take care to ensure that the speed/Mach number has been set correctly.

Assumption #2: For a generic target, no propulsion system is modeled and the target continues to fly at its initial speed unless it is performing either a descending drag or level drag maneuver. For these two maneuvers the target will accelerate to the specified Mach number at 3.0 m/s^2, once established on the final heading (hardwired in the code).

Documentation Reference: SUM page 6-5 and code comparison (TRAP 3.1a vs. TRAP 3.1).

Implications For Model Use: Self explanatory (limitation of selected maneuver).

Assumption #3: The interpolation of the thrust table assumes that there are no throttle settings with a zero thrust value.

Documentation Reference: SUM, Appendix E, PROPTG-7 block (3) and PROPTG-8, block (5).

Implications For Model Use: None, unless user is generating thrust tables. Then, if the minimum thrust at any Mach number and altitude is zero, it may cause program execution to be terminated when the fuel flow table is first accessed at the start of the simulation. None of the thrust values for the first throttle setting should be entered as zero in the table and, to avoid interpolation to a zero value, all the thrust values for the first throttle setting should be of the same sign.

Assumption #4: The target aircraft thrust is assumed to act along the body x-axis.

Documentation Reference: SUM, Appendix-E, PROPTG-7, block (4).

Implications For Model Use: None, unless the target aircraft has a significant thrust misalignment or employs thrust vectoring (in which case this is a limitation and the code would need to be modified).

Assumption #5: The speed control algorithm assumes constant, hard-wired gains in determining the throttle setting required to produce the required change in Mach number.

Documentation Reference: SUM, Appendix E, PROPTG-7, block (4).

Implications For Model Use: Gains should probably vary with both the target aircraft type and the way it is piloted, but to do this would probably not be consistent with the level of fidelity used for the rest of the target aircraft modeling.

Assumption #6: It is assumed that only one type of maneuver will be specified for the flyout. The program does not support the transition from one (uncompleted) maneuver to another.

Documentation Reference: SUM page 6-6.

Implications For Model Use: If a sequence of maneuvers is scheduled using the POLICY routine, it is assumed that the previous maneuver is complete before starting the next one.

Assumption #7: With the pre-programmed option, assumes the target maintains constant Mach number and heading while changing to and maintaining a specified altitude using a specified steady-state altitude rate. Hard-wired gains are used in the altitude control algorithm.

Documentation Reference: SUM pages 6-7 and 6-8, Appendix E, TGNALT-2, block (1).

Implications For Model Use: Self explanatory (limitation of the selected maneuver).

Assumption #8: The non-generic target is used when executing a level turn. The target rolls to a bank angle to produce the specified normal ‘g’ while maintaining a coordinated turn. Altitude and speed are maintained throughout. The turn either ends when a specified heading is reached, or the turn continues until the end of the simulation.

Documentation Reference: SUM pages 6-8 and 6-9.

Implications For Model Use: Self explanatory (limitation of the selected maneuver).

Assumption #9: The non-generic target is used to execute a constant ‘g’ turn. Assumes target will roll to a steady-state bank angle to produce the specified values of normal and horizontal ‘g’. The roll in is not coordinated unless the combination of normal and horizontal ‘g’ represents a coordinated turn. If the roll-in is not coordinated, the pitch and roll dynamics are implemented independently of each other at the same time. The equation for the roll dynamics is based on motion about the flight-path axis and the moment-of-inertia used in deriving the parameters for the roll dynamics should strictly be about this axis.

Documentation Reference: SUM page 6-9, Appendix E, TGNGEE-4.

Implications For Model Use: Self explanatory (limitation of the selected maneuver).

Assumption #10: The S-turn assumes that the target will perform a series of successive turns in opposite directions to 45 degrees either side of the initial heading while maintaining speed and altitude. A user specified period of straight-line flight is used between the successive turns.

Documentation Reference: SUM page 6-11.

Implications For Model Use: Self explanatory (limitation of the selected maneuver).

Assumption #11: The offset option assumes that the target will turn through the specified change in heading while maintaining constant altitude and speed.

Documentation Reference: SUM page 6-16.

Implications For Model Use: Self explanatory (limitation of the selected maneuver).

Assumption #12: The change speed option assumes that the non-generic target is being used. Assumes that constant heading is maintained and that altitude changes in desired fashion (using 5.1.1.2.3.2.1 above) while changing speed to specified Mach number. If an increase in speed is required, it is assumed that a second desired Mach number is specified that is sufficiently in excess of the specified Mach number, to force maximum thrust to be used until the specified Mach number is reached.

Documentation Reference: SUM pages 6-17 and 6-18.

Implications For Model Use: Self explanatory (limitation of the selected maneuver).

Assumption #13: The climb after takeoff option assumes that the non-generic target is being used. The target climbs to a specified final altitude at a specified steady-state altitude rate. Once above a specified intermediate altitude the target commences a turn onto the specified heading. The Mach number is maintained constant throughout.

Documentation Reference: SUM pages 6-20 and 6-21.

Implications For Model Use: Self explanatory (limitation of the selected maneuver).

<u>Assumption #14</u>: The descent to land option assumes that the non-generic target is being used. The target descends to a specified intermediate altitude at a specified steady-state altitude rate at which time the target turns onto the specified heading. Once below a second specified intermediate altitude the target reduces its speed to the specified Mach number. The specified Mach number may or may not be achieved by the time the specified final altitude for the descent is reached. Final altitude and Mach number are then maintained until the end of the simulation. Assumes that the final altitude is high enough to accommodate any overshoot of the descent without the target flying into the ground.

Documentation Reference: SUM pages 6-21 and 6-22.

Implications For Model Use: Self explanatory (limitation of the selected maneuver).

<u>Assumption #15</u>: With the reactive maneuvering option, it is assumed that the target aircraft is pursuing the launch aircraft while closing on it from the rear hemisphere (e.g. to simulate the launch aircraft using a self-protect missile such as an “over-the-shoulder” weapon). Assumption is manifested in the control of the target aircraft speed (non-generic target only).

Documentation Reference: SUM pages 6-18 and 6-19.

Implications For Model Use: Pursuit maneuver can be used for a forward hemisphere engagement by setting the desired Mach number directly in the POLICY.

<u>Assumption #16</u>: The slice option assumes that the target will alter heading by the minimum amount to place the launch aircraft on its beam using the relative position of the launch aircraft at missile launch. Rolls to a bank angle to achieve the specified ‘g’ loading with the roll-in remaining coordinated throughout. Constant Mach number and altitude are maintained throughout.

Documentation Reference: SUM page 6-15.

Implications For Model Use: Self explanatory (limitation of the selected maneuver).

<u>Assumption #17</u>: The level beam option assumes that the target will alter heading by the minimum amount to place the launch aircraft on its beam using the relative position of the launch aircraft at the start of the maneuver. Rolls to a bank angle to achieve the specified ‘g’ loading with the roll-in remaining coordinated throughout. Constant Mach number and altitude are maintained throughout.

Documentation Reference: SUM page 6-14.

Implications For Model Use: Self explanatory (limitation of the selected maneuver).

Assumption #18: The level drag maneuver assumes that the target will alter heading by the minimum amount to place the launch aircraft on its tail. Rolls to a bank angle to achieve the specified ‘g’ loading with the roll-in remaining coordinated throughout. The target continues to react to the changing position of the launch aircraft until the target commences its roll out (however, the direction of turn is determined from the geometry at the start of the maneuver and then remains fixed). Once the target has rolled out it accelerates to the specified Mach number. Constant altitude is maintained throughout.

Documentation Reference: SUM pages 6-11 and 6-12.

Implications For Model Use: Self explanatory (limitation of the selected maneuver).

Assumption #19: The descending drag option assumes that the target will alter heading by the minimum amount to place the launch aircraft on its tail. Rolls to a bank angle beyond 90 degrees to lose altitude with the roll-in remaining coordinated until the aircraft maintains the specified ‘g’ loading. The target continues to react to the changing position of the launch aircraft until the target commences its roll out (however, the direction of turn is determined from the geometry at the start of the maneuver and then remains fixed). Once the target reaches the minimum specified altitude it pulls up to climb to the specified final altitude and accelerates to the specified Mach number once established with a positive climb rate. Altitude control takes precedence over heading to avoid flying into the ground.

Documentation Reference: SUM pages 6-12 and 6-13.

Implications For Model Use: Self explanatory (limitation of the selected maneuver).

Assumption #20: The non-generic target is modeled as a modified point-mass. This includes AOA and roll angle and uses simplified pitch and roll dynamics (rate of change of ‘g’ in pitch and maximum roll rate together with roll time constant in roll). The sideslip angle is always zero (which represents a coordinated turn).

Documentation Reference: SUM pages 2-3, 6-6 and 6-7.

Implications For Model Use: Does not support detailed modeling of target aircraft airframe dynamics. Parameters for pitch and roll dynamics must be chosen to match the expected flight regime for the intercept.

Projected Corrections or Changes: Possibly make the parameters for pitch and roll dynamics a table based on the target aircraft flight condition.

Assumption #21 The generic target is modeled as a simple point mass. It has zero AOA and roll angle and the required accelerations along and normal to the flight-path (in the horizontal and vertical planes) are generated instantaneously.

Documentation Reference: SUM page 6-5, SUM page 6-22, and code comparison (TRAP 3.1a vs. TRAP 3.1).

Implications For Model Use: Does not support the modeling of the generic target aircraft attitude which will affect the calculation of aspect dependent signature.

Assumption #22: The sideslip angle of the target aircraft is always assumed to be zero which represents a coordinated turn.

Documentation Reference: SUM page 6-109

Implications For Model Use: Target aircraft pointing in sideslip is not supported.

Assumption #23: The second target aircraft is assumed to be identical to the primary target (this includes its mass properties, aerodynamic properties, propulsion characteristics and signature).

Documentation Reference: SUM page 6-5.

Implications For Model Use: Dissimilar targets cannot be modeled in the same scenario.

Assumption #24: The second target is constrained to follow a flight-path determined by the maneuvering of the primary target aircraft. For horizontal position it will use either a time delayed flight path, a constant inertial offset, or a constant relative offset relative to the primary target. In the vertical plane the second target has a constant altitude offset from the primary target and is always assumed to have the same flight-path pitch angle as the primary target.

Documentation Reference: SUM page 6-110.

Implications For Model Use: Multiple, independent targets are not allowed (however, the intent of this feature is to see how missiles will cope with two closely spaced targets, which is adequately supported by the assumption).

Assumption #25: If the aerodynamic limits of the second target are exceeded the second target is still constrained to follow its prescribed path relative to the primary target.

Documentation Reference: SUM page 6-110.

Implications For Model Use: A warning message is printed out by the program and it is up to the user to alter the scenario such that the second target flies within its aerodynamic limits.

Assumption #26: If the propulsion limits of the second target are exceeded the second target is still constrained to follow its prescribed path relative to the primary target.

Documentation Reference: SUM page 6-110.

Implications For Model Use: A warning message is printed out and it is up to the user to alter the scenario such that the second target flies within its propulsion limits.

1.3 Signature

1.3.3 RF

Assumption #1: Assumes that the tabular RCS data are provided either as cone-angle or great-circle sweeps.

Documentation Reference: SUM page 6-61.

Implications For Model Use: None unless user is generating RCS data. Then data must be in the appropriate format.

Assumption #2: For the bistatic case, it is assumed that the RCS value will be the one obtained by bisecting the angle between the line-of-sight from the target to the illuminator and the line-of-sight from the target to the receiver.

Documentation Reference: SUM page 6-61.

Implications For Model Use: Allows a monostatic RCS table (i.e. greatly reduced in size compared to the bistatic case) to be used for the sacrifice of some fidelity.

Assumption #3: A metallic target is assumed which produces a 180 degree phase shift due to reflection (i.e. if the illuminator and receiver have matched circular polarization the RCS will be zero).

Documentation Reference: SUM page 6-61.

Implications For Model Use: Valid only for metallic targets.

5.0 CM/CCM

Assumption #1: It is assumed that only a single jammer will be carried by each of up to two targets.

Documentation Reference: SUM page 6-59.

Implications For Model Use: Self explanatory (there are a maximum of two targets).

5.1.1 On-Board

Assumption #1: The antenna orientation remains fixed relative to target aircraft.

Documentation Reference: SUM page 6-6.

Implications For Model Use: Self explanatory.

5.1.3 Standoff

Assumption #1: Off-board jammers are assumed to be ground based with a fixed position (note that a velocity can be specified for the off-board jammer, but no position updates are performed). Antenna orientation can be different for each jammer but remains fixed throughout the simulation.

Documentation Reference: SUM pages 6-6 and 6-56.

Implications For Model Use: If the position of ground based jammers is critical then they should have zero velocity assigned to them.

II LAUNCH PLATFORM

1.1 Configuration

1.1.1 Mass Properties

Assumption #1: For the non-generic launch aircraft only the mass is modeled. The launch aircraft is assumed to have a constant center-of-gravity location.

Documentation Reference: SUM page 6-24.

Implications For Model Use: Does not support detailed modeling of the launch aircraft airframe dynamics.

Assumption #2: No moments-of-inertia are modeled (although the effects of the moments-of-inertia are implicitly included in the model of the pitch and roll dynamics, see 5.1.2.2.5).

Documentation Reference: SUM page 6-24.

Implications For Model Use: Does not support detailed modeling of the launch aircraft airframe dynamics.

Assumption #3: No mass properties are modeled for the generic launch aircraft (the required accelerations are generated directly).

Documentation Reference: SUM page 6-24.

Implications For Model Use: Does not support detailed modeling of the launch aircraft airframe dynamics.

1.2 Movement

Assumption #1: The calculation of the horizontal lead angle when aiming the launch aircraft at the start of the simulation assumes that the target is flying at constant altitude on a heading of zero. The calculation of the vertical lead angle assumes that the target is flying at constant altitude on a heading of zero and that the horizontal line-of-sight from the launch aircraft to the target is aligned with this heading.

Documentation Reference: SUM, Appendix E, LEADSU-3 and 4, block (2).

Implications For Model Use: If the assumptions are not met, then incorrect lead angles will be calculated.

Projected Corrections or Changes: Calculations should be reformulated to allow for arbitrary flight path angles.

Assumption #2: If the initial speed is input as zero, then the initial Mach number is used to set the initial speed. If the initial Mach number has been input as zero, then the initial speed is used to set the initial Mach number. If both the initial speed and Mach number are input as non-zero quantities, whichever is read last from the data file will be retained and used to set the other.

Documentation Reference: SUM, Appendix E, ACINIT-8, block (4).

Implications For Model Use: User must take care to ensure that the speed/Mach number has been set correctly.

Assumption #3: No propulsion system is modeled for the generic launch aircraft and it is assumed that the speed of the generic launch aircraft remains constant at its initial value.

Documentation Reference: SUM page 6-24.

Implications For Model Use: Self explanatory (limitation of generic launch aircraft maneuvers).

Assumption #4: The interpolation of the thrust table assumes that there are no throttle settings with a zero thrust value.

Documentation Reference: SUM, Appendix E, PROPAC-6 block (3) and PROPAC-7, block (5).

Implications For Model Use: If the minimum thrust at any Mach number and altitude is zero it may cause program execution to be terminated when the fuel flow table is first accessed at the start of the simulation. None of the thrust values for the first throttle setting should be entered as zero in the table and, to avoid interpolation to a zero value, all the thrust values for the first throttle setting should be of the same sign.

Assumption #5: The aircraft thrust is assumed to act along the body x-axis.

Documentation Reference: SUM, Appendix-E, PROPAC-6, block (4).

Implications For Model Use: None unless the aircraft has a significant thrust misalignment or employs thrust vectoring (in which case the code would need to be modified).

Assumption #6: The speed control algorithm assumes constant, hard-wired gains in determining the throttle setting required to produce the required change in Mach number.

Documentation Reference: SUM, Appendix E, PROPAC-6, block (4).

Implications For Model Use: Gains should probably vary with both the aircraft type and the way it is piloted, but to do this would probably not be consistent with the level of fidelity used for the rest of the aircraft modeling.

Assumption #7: It is assumed that only one type of maneuver will be specified for the flyout. The program does not support the transition from one (uncompleted) maneuver to another.

Documentation Reference: SUM page 6-25.

Implications For Model Use: If a sequence of maneuvers is scheduled using the POLICY routine, it is assumed that the previous maneuver is complete before starting the next one.

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Assumption #8: The change/maintain altitude option assumes the launch aircraft maintains constant Mach number and heading while changing to and maintaining a specified altitude using a specified steady-state altitude rate. Hard wired gains are used in the altitude control algorithm.

Documentation Reference: SUM page 6-26, Appendix E, ACNALT-1, block (1).

Implications For Model Use: Self explanatory (limitation of selected maneuver).

Assumption #9: The level turn option assumes that the non-generic launch aircraft is being used. The launch aircraft rolls to a bank angle to produce the specified normal 'g' while maintaining a coordinated turn. Altitude and speed are maintained throughout. The turn continues until the end of the simulation.

Documentation Reference: SUM pages 6-27.

Implications For Model Use: Self explanatory (limitation of selected maneuver).

Assumption #10: The constant 'g' option assumes that the non-generic launch aircraft is being used. Assumes launch aircraft will roll to a steady-state bank angle to produce the specified values of normal and horizontal 'g'. The roll in is coordinated until the steady-state bank angle is achieved then the normal 'g' is increased or decreased to match the specified value of normal 'g'. The equation for the roll dynamics is based on motion about the flight-path axis and the moment-of-inertia used in deriving the parameters for the roll dynamics should strictly be about this axis.

Documentation Reference: SUM page 6-28, Appendix e, ACNGEE-4.

Implications For Model Use: Self explanatory (limitation of selected maneuver).

Assumption #11: An offset maneuver assumes that the launch aircraft will turn through the specified change in heading while maintaining constant altitude and speed.

Documentation Reference: SUM pages 6-31 and 6-32.

Implications For Model Use: Self explanatory (limitation of selected maneuver).

Assumption #12: When the pursuit of target aircraft option is selected, assumes that the launch aircraft is pursuing the target aircraft while closing on it from the rear hemisphere. Assumption is manifested in the control of the launch aircraft speed (non-generic launch aircraft only).

Documentation Reference: SUM pages 6-29 and 6-30.

Implications For Model Use: Pursuit maneuver can be used for a forward hemisphere engagement by setting the desired Mach number directly in the POLICY routine.

Assumption #13: No aerodynamics are modeled for the generic launch aircraft.

Documentation Reference: SUM page 6-32.

Implications For Model Use: Does not support modeling of the generic launch aircraft attitude (will affect the missile attitude during carriage and at launch).

Assumption #14: The non-generic launch aircraft is modeled as a modified point-mass. This includes AOA and roll angle and uses simplified pitch and roll dynamics (rate of change of ‘g’ in pitch and maximum roll rate together with roll time constant in roll). The sideslip angle is always zero (which represents a coordinated turn.

Documentation Reference: SUM pages 2-2, 6-25.

Implications For Model Use: Does not support detailed modeling of launch aircraft airframe dynamics. Parameters for pitch and roll dynamics must be chosen to match the expected flight regime for the intercept.

Projected Corrections or Changes: Possibly make the parameters for pitch and roll dynamics a table based on the launch aircraft flight condition.

Assumption #15: The generic launch aircraft is modeled as a simple point mass. It has zero AOA and roll angle and the required accelerations along and normal to the flight-path (in the horizontal and vertical planes) are generated instantaneously. (Note: In TRAP 3.1 the point-mass generic launch aircraft was restricted to non-maneuvering flight - the maneuver options were introduced in TRAP 3.1a.)

Documentation Reference: SUM page 6-32 and code comparison (TRAP 3.1a vs. TRAP 3.1).

Implications For Model Use: Does not support modeling of the generic launch aircraft attitude (will affect the missile attitude during carriage and at launch).

Assumption #16: The sideslip angle of the launch aircraft is always assumed to be zero.

Documentation Reference: SUM page 6-115.

Implications For Model Use: Pointing of the launch aircraft in sideslip is not supported.

2.4 AI Radar

2.4.3 Antenna

Assumption #1: An outer-pitch/inner-yaw gimbal arrangement is assumed.

Documentation Reference: SUM page 6-36.

Implications For Model Use: If other gimbal arrangements need to be modeled, the code must be modified.

Assumption #2: Assumes either (1) electronic scanning in both pitch and yaw, or (2) mechanical scanning in pitch with electronic scanning in yaw, or (3) mechanical scanning in both pitch and yaw.

Documentation Reference: SUM page 6-36.

Implications For Model Use: If another scan type is required the code must be modified.

Assumption #3: The perfect AI radar model assumes that the x-axis of the mainbeam is aligned with the line-of-sight to the target, provided gimbal angle limits and gimbal rate limits are not exceeded.

Documentation Reference: SUM pages 6-36 and 6-37.

Implications For Model Use: Self explanatory (this is a limitation of the fidelity of the modeling).

2.4.4 Signal Processing

Assumption #1: Probability of detection for realistic AI radar is based on Swerling model (cases 0 through 4).

Documentation Reference: SUM pages 6-34 and 6-35.

Implications For Model Use: The user must choose the Swerling model to most closely represent the particular circumstance.

Assumption #2: Perfect AI radar will always acquire target if direct line-of-sight to target is unobstructed by the curvature of the Earth (with zero altitude terrain).

Documentation Reference: SUM page 6-37.

Implications For Model Use: Self explanatory.

2.4.5 Target Tracking

Assumption #1: The time step parameters for the range tracking loop are assumed to be set in the POLICY routine.

Documentation Reference: SUM page 6-35.

Implications For Model Use: User must set these parameters in the POLICY routine.

Projected Corrections or Changes: The whole of the AI radar modeling is due to be revisited.

Assumption #2: Assumes that the line-of-sight errors from the angle tracker can be obtained by applying a static gain error slope to the geometric line-of-sight errors.

Documentation Reference: SUM page 6-35.

Implications For Model Use: Self explanatory (this is a limitation of the fidelity of the modeling).

Projected Corrections or Changes: The whole of the AI radar modeling is due to be revisited.

III MISSILE

1.1 Configuration

1.1.1 Mass Properties

Assumption #1: Constant center-of-gravity location assumed for propellant during motor burn (i.e., radial burn assumed).

Documentation Reference: SUM page 6-44.

Implications For Model Use: The center-of-gravity location will not be correctly modeled for an ‘end burning’ rocket motor which will be reflected in the missile maneuverability during motor burn only. Additional code would need to be written to model this case.

Projected Corrections or Changes: The capability to include a variable center-of-gravity location for the propellant during motor burn is a projected change.

1.1.2 Moments of Inertia

Assumption #1: Products-of-inertia are assumed to be zero, i.e. missile has two planes of symmetry (or if asymmetries are present then the products-of-inertia are small enough to be neglected). Does not apply to point-mass missile model.

Documentation Reference: SUM page 6-44, 6-107.

Implications For Model Use: Provided the missile has two planes of symmetry, this assumption is valid. Inaccuracies will be introduced if the missile has only one plane of symmetry (e.g. an aircraft type configuration) or no planes of symmetry (due to irregular placement of excrescences such as cable ducts). However, the level of asymmetry for most tactical missiles is small enough that the products of inertia will be negligible in comparison to the principal moments of inertia. The assumption allows for the use of simplified rotational equations of motion.

Projected Corrections or Changes: To incorporate the products-of-inertia would require a major revision of the rotational equations of motion and is unlikely to occur unless there is a need to model a specific missile system which has significant asymmetries.

Assumption #2: Rates of change of the moments-of-inertia are not included in the equations of motion. Does not apply to point-mass missile model (see also equations of motion).

Documentation Reference: SUM, Appendix E, MISLEQ-3, block (10), TVCMSQ-3, block (10).

Implications For Model Use: May have a significant effect on airframe response during motor burn if the missile is at its maneuver limit (when away from the maneuver limit, the effect is likely to be reduced considerably due to the presence of the autopilot).

Projected Corrections or Changes: Rates of change of the moments-of-inertia have been introduced in TRAP 4.0.

1.2 Movement

1.2.1 Propulsion

Assumption #1: The mixing of aerodynamic control systems with TVC is not currently supported. It is assumed that control in all planes is provided by aerodynamic surfaces, or control in all planes is provided by TVC.

Documentation Reference: SUM, Appendix E, FLYMSL-5, block (7).

Implications For Model Use: None, unless the user is developing a new or modified missile system.

Projected Corrections or Changes: Incorporation of mixed control types may make system development easier.

1.2.2 Aero/Kinematics

Assumption #1: When the missile body attitude is initialized, it is assumed that the launch aircraft is at zero body roll angle and zero sideslip angle.

Documentation Reference: SUM, Appendix E, MSINIT-4, block (2).

Implications For Model Use: None for the non-generic aircraft, unless the initialization of the launch aircraft is changed to allow for non-zero roll angle, or if the modeling of the launch aircraft is expanded to include non-zero sideslip angles. For the generic aircraft, non-zero body roll angles are already permitted which will be in conflict with the initialization of the missile. Therefore, the generic launch aircraft should always be set to an initial roll angle of zero.

Projected Corrections or Changes: Launch aircraft roll angle and sideslip angle should be used in initializing the missile attitude (instead of assuming that they will be zero).

Assumption #2: If the missile is launched from an aircraft that is not at zero roll angle, missile is assumed to roll instantaneously to zero body roll angle (but no roll acceleration or roll rate is modeled).

Documentation Reference: SUM page 6-37

Implications For Model Use: User should be aware that the missile is constrained to fly at zero body roll angle. Instantaneous rolling of the airframe requires the seeker to be reinitialized and no seeker tracking can be performed during the instantaneous roll.

Projected Corrections or Changes: In TRAP 4.0, some control options now allow non-zero missile body roll angles (e.g. bank-to-turn and constant roll rate). For these options there is no need to instantaneously roll the missile at launch.

Assumption #3: Missile always assumed to be at zero body roll angle.

Documentation Reference: SUM page 6-37.

Implications For Model Use: Will not correctly model a rolling airframe missile (e.g. the spiral motion superimposed on the flight path) or a bank-to-turn missile. This constraint also makes it impossible for the missile to fly through the vertical.

Projected Corrections or Changes: In TRAP 4.0, some control options now allow non-zero missile body roll angles (e.g. bank-to-turn and constant roll rate).

<u>Assumption #4</u>: The pitch-plane and yaw-plane aerodynamic characteristics are assumed to be independent of each other, which is an error if the aerodynamic characteristics are non-linear.

Documentation Reference: SUM page 6-94.

Implications For Model Use: For non-linear aerodynamic characteristics (in the pitch and yaw planes), the current treatment will not give the correct aerodynamic characteristics when the total AOA plane is not aligned with either the pitch or yaw plane.

Projected Corrections or Changes: It is intended to treat aerodynamic characteristics as a function of total AOA and aerodynamic roll angle as part of the planned enhancements to the aerodynamic methodology.

<u>Assumption #5</u>: It is assumed that the aerodynamic characteristics are provided as a function of the tangent definitions of the AOA and sideslip.

Documentation Reference: SUM page 6-95.

Implications For Model Use: None, unless the user is generating aerodynamic characteristics for use in the program.

Projected Corrections or Changes: It is intended to treat aerodynamic characteristics as a function of total AOA and aerodynamic roll angle as part of the planned enhancements to the aerodynamic methodology.

<u>Assumption #6</u>: The equations of motion assume a flat, non-rotating Earth as the inertial reference.

Documentation Reference: SUM, Appendix A, page A-2

Implications For Model Use: Neglects an additional z-component in the translational equations of motion. At a Mach number of 3.0, this term amounts to about 2% of the vehicle weight, which increases at higher speeds. The effect will only be significant for missiles that have long periods of cruising flight at high speeds. Neglecting these effects leads to a much simpler set of equations of motion.

<u>Assumption #7</u>: The equations of motion assume a stationary atmosphere.

Documentation Reference: SUM, Appendix A, page A-2

Implications For Model Use: For the vehicle dynamic response, the assumption is valid as long as the missile true air speed is large relative to the wind speed, or if the missile only changes heading slowly. This assumption is probably valid in most cases and allows a much simpler set of equations of motion. However, if position relative to a location on the ground is important (e.g. a ground based target) then wind effects should be taken into account. This latter effect could be included by applying translations to the positions calculated in the stationary atmosphere.

<u>Assumption #8</u>: The missile is assumed to be a rigid body.

Documentation Reference: SUM, Appendix A, page A-2.

Implications For Model Use: Effects due to elastic deformation of the structure and the motion of hinged parts is not considered, but results in much simplified equations of motion. Effects will probably only be significant for large lateral maneuvers in which case the error introduced will still be very small compared to the other uncertainties that arise, for instance in the aerodynamic coefficients.

<u>Assumption #9</u>: The lift and drag coefficients are calculated from the axial force coefficient and normal force coefficient as a transformation from body-axes to stability axes, i.e. it is assumed that the sideslip angle is zero.

Documentation Reference: SUM, Appendix E, MISLEQ-5, block (3), PMISEQ-6, block (6) and TVCMSQ-5, block (3).

Implications For Model Use: Currently, the lift coefficient is not used anywhere else in the code. The drag coefficient is only used in the missile propulsion routine to calculate the thrust required to cruise at a specific Mach number for a turbine or ramjet propulsion system. Such a system will probably be operating under conditions of zero sideslip and the assumption will therefore be valid. However, if the lift and drag coefficients are to be used in any other way they should be recalculated to give the correct values by taking into account the transformation through the angle-of-sideslip as well as the AOA.

Projected Corrections or Changes: Calculation should be reformulated to take into account the angle-of-sideslip (SUM, Appendix E, MISLEQ-5, block (3), PMISEQ-6, block (6) and TVCMSQ-5, block (3)).

<u>Assumption #10</u>: Before the missile is launched, it is assumed to be rigidly attached to the launch aircraft and its state is updated relative to the values for the launch platform.

Documentation Reference: SUM page 6-115.

Implications For Model Use: Self explanatory.

<u>Assumption #11</u>: The 3-DOF-PITCH missile is constrained to flight in the vertical plane with zero sideslip and zero body-axes rotational rates in yaw and roll.

Documentation Reference: SUM page 6-117.

Implications For Model Use: Only allows for missile flight in the vertical plane (limitation of this level of simulation).

<u>Assumption #12</u>: The 3-DOF-YAW missile is constrained to flight in the horizontal plane with zero AOA and zero body-axes rotational rates in pitch and roll. Note that this is

equivalent to neglecting the effect of gravity (missile maintains altitude without generating lift to counteract its weight).

Documentation Reference: SUM page 6-117.

Implications For Model Use: Only allows for missile flight in the horizontal plane (limitation of this level of simulation).

<u>Assumption #13</u>: The 5-DOF missile maintains zero body roll angle by generating an appropriate body roll rate in order to maintain zero body roll angle acceleration (performed in the equations of motion). This roll rate is used in the update of the reference-axes to body-axes transformation matrix. It is assumed that the body roll rate is sufficient to maintain zero body roll angle and the body roll angle is set to zero (without checking its actual value extracted from the transformation matrix).

Documentation Reference: SUM page 6-118.

Implications For Model Use: For the 5-DOF missile, it is assumed that the roll rate required to maintain zero roll angle will always be available. However, at pitch angles approaching the vertical the roll rate demand may be limited. In this case, a non-zero roll angle will develop and, although the roll angle is set to zero, an incorrect roll rate will be carried through to the equations of motion.

Projected Corrections or Changes: Rectified in TRAP 4.0 with the reformulation of the equations of motion to allow non-zero body roll angles for some roll control options (constant body roll rate and bank-to-turn).

<u>Assumption #14</u>: The 6-DOF missile maintains zero body roll angle by the roll autopilot demanding appropriate control deflections. These control deflections produce an angular roll acceleration which is integrated to obtain the body roll rate which is used in the update of the reference-axes to body-axes transformation matrix. The actual value of body roll angle extracted from this matrix is then used by the program (however, many other parts of the program assume implicitly that the value of the body roll angle is zero and non-zero body roll angles are not in general supported).

Documentation Reference: SUM page 6-118.

Implications For Model Use: If the roll autopilot is unable to maintain zero body roll angle, the assumption of zero body roll angle necessary in many parts of the program will not be valid and the results will be suspect.

Projected Corrections or Changes: Rectified in TRAP 4.0 with the reformulation of the equations of motion to allow non-zero body roll angles for some roll control options (constant body roll rate and bank-to-turn).

<u>Assumption #15</u>: For the point-mass missile, the update of the reference-axes to body-axes transformation matrix makes the assumption of constant body-axes rates.

Documentation Reference: SUM page 6-118.

Implications For Model Use: Missile body attitudes are unlikely to accurately represent the transient (out of trim) airframe response and may result in seeker limitations (e.g. hitting gimbal limits) that would not be experienced with a higher fidelity model of the airframe. However, this allows a "real" seeker to be attached to a point-mass airframe which will allow a detailed seeker model to be developed while retaining a simplified model of the airframe.

Trimmed Forces (Point-mass)

Assumption #1: It is assumed that the aerodynamic characteristics have been provided for a '+' configuration missile (if the missile is in the 'x' configuration TRAP generates equivalent angles-of-attack for a '+' configuration).

Documentation Reference: SUM page 6-95.

Implications For Model Use: None, unless the user is generating aerodynamic characteristics for use in the program.

Projected Corrections or Changes: This is likely to be reviewed during the planned enhancements to be made to the aerodynamic methodology.

Assumption #2: It is assumed that the aerodynamic characteristics are a function of trimmed AOA and sideslip.

Documentation Reference: SUM page 6-103.

Implications For Model Use: The transient (out-of-trim) response of the missile is not modeled. This will be reflected both in the maneuverability and the drag exhibited by the missile. However, the effect is likely to be relatively small, except for short range intercepts requiring high levels of lateral acceleration.

Projected Corrections or Changes: Even with the intended shift to using total AOA and roll angle as part of the planned aerodynamic methodology enhancements, trim conditions are still likely to be used for the point-mass modeling. The reduction in fidelity is a trade-off against the much reduced data set that is required.

Assumption #3: The normal acceleration demanded by the missile guidance scheme will always be met subject to the maximum trimmed aerodynamic limits and a user-specified maximum rate of change of the missile AOA (this prevents angles-of-attack being produced instantaneously). The limits are applied separately in each of the planes of the fins.

Documentation Reference: SUM page 6-103.

Implications For Model Use: The application of these limits (e.g. a fixed value of maximum AOA rate), may impose artificial limits on the missile in some portions of its flight.

Projected Corrections or Changes: This area will be reviewed during the planned aerodynamic methodology enhancements with a view to obtaining a representative response throughout the whole flight of the missile.

<u>Assumption #4</u>: For a missile in the 'x' configuration, the acceleration command in the 'primary' acceleration plane (the fin plane closest to the demanded maneuver plane) is limited to the user specified amount. The acceleration demand in the other fin plane is then the largest that will still allow the smaller of the true pitch and yaw accelerations to be met. This approach avoids saturation in both fin planes - saturation would result in no net acceleration being generated in the plane containing the smaller of the true pitch and yaw acceleration demands.

Documentation Reference: SUM page 6-100 and 6-102.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case the limiting should be reviewed to see if it is appropriate for the system being modeled.

<u>Assumption #5</u>: The axial force contribution due to control surface deflection is calculated from the control surface deflection required to produce the current trimmed AOA (no actual control system is modeled for point-mass missiles).

Documentation Reference: SUM page 6-104.

Implications For Model Use: The axial force is not properly modeled during the transient response (out of trim condition) of the missile. The effect will be small except for short range intercepts requiring high levels of lateral acceleration.

The reduction in fidelity in using trimmed aerodynamic characteristics is a trade-off against the much reduced data set that is required.

<u>Assumption #6</u>: It is assumed that a symmetric configuration is being modeled (same characteristics in pitch and yaw).

Documentation Reference: SUM page 6-104.

Implications For Model Use: If the configuration is not symmetric then the axial force will not be correctly calculated. However, non-symmetric missiles tend to perform most of their maneuvering in one plane with the control deflection in the other plane remaining small which tends to reduce the effect of this assumption.

<u>Assumption #7</u>: Changes in the aerodynamic angles are produced 'instantaneously' in the point-mass aerodynamics routines (even though the maximum rate of change is limited). It is assumed that the flight-path angles are continuous, which means that there is a corresponding 'instantaneous' change in the body attitude which is calculated before resolving the various forces acting on the missile.

Documentation Reference: SUM page 6-106.

Implications For Model Use: This is one of the reasons why missile flight near the vertical may not be possible in the model (when near the vertical this assumption, combined with the requirement for zero body roll angle, can lead to the calculation of a body attitude that is physically unattainable).

Projected Corrections or Changes: TRAP 4.0 now allows for missile flight at arbitrary body roll angles. This has allowed the demands associated with an instantaneous change in body attitude to be relaxed, and flight through the vertical is now possible.

Assumption #8: The control of the missile is assumed to be provided by aerodynamic controls (TVC is not modeled).

Documentation Reference: SUM, page 108.

Implications For Model Use: A TVC system cannot be modeled at the point-mass level without specific code being written.

Projected Corrections or Changes: During the planned enhancements to the aerodynamic methodology it is intended to add the capability to model a TVC missile at the point-mass level.

Assumption #9: The thrust is assumed to act along the missile body x-axis (i.e. no lateral force and no moments generated due to the thrust).

Documentation Reference: SUM, page 6-106.

Implications For Model Use: None, unless the user is developing a new or modified missile which has a thrust offset, then system specific code would have to be introduced in the equations of motion.

Projected Corrections or Changes: During the planned enhancements to the aerodynamic methodology it is intended to add the capability to model a TVC missile at the point-mass level. This will allow for non-axial thrust in the equations of motion.

Generalized Forces and Moments (N-DOF)

Assumption #1: It is assumed that the aerodynamic characteristics are provided in the true pitch and yaw planes of the missile (for an ‘x’ configuration missile these planes are at 45 degrees to the planes of the fins).

Documentation Reference: SUM page 6-95.

Implications For Model Use: None, unless the user is generating aerodynamic characteristics for use in the program.

Projected Corrections or Changes: It is intended to treat aerodynamic characteristics as a function of total AOA and aerodynamic roll angle as part of the planned enhancements to the aerodynamic methodology.

Assumption #2: For a missile in the ‘+’ configuration, it is assumed that the pitch control deflection (output from the control system model) is applied to the two control surfaces lying normal to the pitch plane controls (to produce a maneuver demand in the xz-plane of the body).

Documentation Reference: SUM page 6-95.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case the existing convention should be observed.

Projected Corrections or Changes: This is likely to be reviewed during the planned enhancements to the aerodynamic methodology.

<u>Assumption #3</u>: For a missile in the 'x' configuration, it is assumed that the pitch control deflection (output from the control system) is applied to all four controls (to produce a maneuver demand in the xz-plane of the body). Note that in the control system model each surface is deflected separately, but the separate control deflections are resolved to give the equivalent pitch, yaw and roll deflections.

Documentation Reference: SUM page 6-95.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case the existing convention should be observed.

Projected Corrections or Changes: This is likely to be reviewed during the planned enhancements to the aerodynamic methodology.

<u>Assumption #4</u>: The pitch-moment coefficient data are assumed to be about the specified reference center of gravity.

Documentation Reference: SUM page 6-96.

Implications For Model Use: None, unless the user is developing aerodynamic characteristics for use in the program, in which case the existing convention should be observed.

<u>Assumption #5</u>: For a missile in the '+' configuration, it is assumed that the yaw control deflection (output from the control system model) is applied to the two control surfaces lying normal to the yaw plane (to produce a maneuver demand in the xy-plane of the body).

Documentation Reference: SUM page 6-97.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case the existing convention should be observed.

Projected Corrections or Changes: This is likely to be reviewed during the planned enhancements to the aerodynamic methodology.

<u>Assumption #6</u>: For a missile in the 'x' configuration, it is assumed that the yaw control deflection (output from the control system model) is applied to all four controls (to produce a maneuver demand in the xy-plane of the body). Note that in the control system model each surface is deflected separately, but the separate control deflections are resolved to give the equivalent pitch, yaw and roll deflections.

Documentation Reference: SUM page 6-97.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case the existing convention should be observed.

Projected Corrections or Changes: This is likely to be reviewed during the planned enhancements to the aerodynamic methodology.

<u>Assumption #7</u>: The yaw-moment coefficient data are assumed to be about the specified reference center of gravity.

Documentation Reference: SUM page 6-97.

Implications For Model Use: None, unless the user is developing aerodynamic characteristics for use in the program, in which case the existing convention should be observed.

<u>Assumption #8</u>: No incremental axial force coefficient is calculated for the roll control deflections generated by the 6-DOF missile model, and no equivalent roll control deflections are calculated for the 5-DOF or point-mass missile models (and hence no incremental axial force coefficient due to roll control deflection).

Documentation Reference: SUM, Appendix E, AERDRG-10, block (11).

Implications For Model Use: Introduces an underestimate of the axial force coefficient. However, because missiles generally have a low moment-of-inertia in roll, the calculated roll control deflections are likely to be small and consequently the incremental axial force would be small. However, for a real missile at high angles-of-attack large uncommanded rolling moments can be generated due to asymmetric flowfields around the missile and it may require large roll deflections to null out these rolling moments.

Projected Corrections or Changes: Would need to be implemented if the fidelity of the aerodynamic modeling was improved to include high AOA, asymmetric effects (possible under the planned enhancements to the aerodynamic methodology).

<u>Assumption #9</u>: It is assumed that the missile accelerometers are configured to provide a reading of -1.0 g in the positive z-direction (downwards) when the missile is in straight and level flight, which is equivalent to 0.0 g when the missile is in free-fall ballistic trajectory.

Documentation Reference: SUM page 6-108.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case the existing convention should be followed.

<u>Assumption #10</u>: The thrust is assumed to act along the missile body x-axis (i.e. no lateral force and no moments generated due to the thrust)

Documentation Reference: SUM, page 6-107.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case the equations of motion can be modified using the TVC equations of motion as a guide but with a fixed thrust offset.

Generalized Thrust Vector Control (N-DOF)

Assumption #1: Equations of motion are identical to the generalized equations of motion for aerodynamic control except that the thrust is no longer assumed to act along the missile body x-axis.

Documentation Reference: SUM page 6-108.

Implications For Model Use: The same assumptions apply as for the generalized aerodynamic control case except for the differences indicated in the following paragraphs.

Assumption #2: A specific TVC arrangement is assumed which uses a gimballed nozzle with an outer-yaw/ inner-pitch gimbal.

Documentation Reference: SUM page 6-108.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case the equations should be modified to reflect the particular gimbal arrangement, or other TVC arrangement if applicable.

Assumption #3: No loss of thrust is assumed due to the use of TVC.

Documentation Reference: SUM, Appendix E, TVCMSQ-5, block (4).

Implications For Model Use: Probably a relatively small effect if a gimballed nozzle is used. However, other forms of TVC (such as spoilers) will produce a significant reduction in thrust depending on the amount of control deflection, and would require a modification of the equations of motion.

Assumption #4: TVC in roll is assumed to be provided by a pair of nozzles independent of the TVC pitch and yaw control and is assumed to provide a pure rolling moment (no net force).

Documentation Reference: SUM page 6-108.

Implications For Model Use: Since the deflection of the nozzles to provide the pitch and yaw moments is considered to be independent of the deflection to produce the roll moment, this will introduce inaccuracies in resolving the forces. The total deflections of each nozzle should be considered.

2.0 SENSORS

Assumption #1: For all seeker types (except 'UNKNOWN") the seeker is only allowed to acquire the target if the launch aircraft-to-target range is below a specified range (RAQUIR).

Documentation Reference: SUM, Appendix E, FLYMSL-4, block (4).

Implications For Model Use: If the missile is launched at a range greater than specified (RAQUIR) from the target, the missile will not be able to acquire the target until the launch platform-to-target range falls below RAQUIR. By the same token, if the launch platform-to-target range ever increases beyond RAQUIR following missile launch (e.g. due to launch platform and/or target maneuvering) then acquisition will be lost.

Projected Corrections or Changes: It appears (from in-code comments) as if the acquisition range RAQUIR was intended to be used only in the period before missile launch. If so, this condition should be applied in the code.

2.3 IR

2.3.1 FOV

Assumption #1: Field-of-view limiting assumes a rectangular field-of-view for the seeker.

Documentation Reference: SUM page 6-54.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case the FOV limiting should reflect the configuration for the particular seeker.

Assumption #2: Although an out-of-field-of-view flag is set if the target is outside the field-of-view, it is not used (i.e. the seeker continues to track the target).

Documentation Reference: SUM page 6-54.

Implications For Model Use: Guidance commands will still be produced as if the seeker had a FOV that was large enough to maintain the target in its sight, which will lead to optimistic performance of the seeker.

2.3.2 Signal Processing

Assumption #1: Seeker is assumed to have lock-on if the signal-to-noise ratio is greater than the specified minimum value. If there is an insufficient signal-to-noise ratio, it is assumed that the line-of-sight tracking errors will be zero (i.e. no steering command generated).

Documentation Reference: SUM page 6-54.

Implications For Model Use: Self explanatory (limitation of the fidelity of the seeker model).

2.3.3 Target Tracking

Assumption #2: Line-of-sight tracking errors are calculated geometrically (difference between the seeker x-axis and the line-of-sight to the target).

Documentation Reference: SUM page 6-53.

Implications For Model Use: Self explanatory (limitation of the fidelity of the model).

2.4 RF Seeker

2.4.1 Transmitter

Assumption #1: Semi-active source - The illuminator is assumed to be carried on the launch aircraft and aligned with AI radar.

Documentation Reference: SUM pages 6-34, 6-37 and 6-59.

Implications For Model Use: Self explanatory. Does not allow illumination of the target from a cooperative source (such as another aircraft).

Assumption #1: Active source - The illuminator is carried on the missile and is assumed to be aligned with the receive antenna. However, the illuminator is not assumed to share the same antenna as the receiver, although this would usually be the case.

Documentation Reference: SUM pages 6-68 and 6-69.

Implications For Model Use: Self explanatory. User must ensure that the choice of illuminator parameters is appropriate.

2.4.2 Receiver

Assumption #1: Operating temperature of radar receiver (all types) is assumed to be 290K. This is set by the parameter RCVTRF (hard wired in the code, not an input parameter).

Documentation Reference: SUM page 6-48.

Implications For Model Use: If the operating temperature is significantly different from 290K it will affect the receiver noise power and should be reflected by changing the value of RCVTRF.

Assumption #2: It is assumed that all radar receivers will be four-beam monopulse systems (in either a ‘plus’ or ‘square’ configuration).

Documentation Reference: SUM pages 6-54 and 6-55.

Implications For Model Use: Self explanatory (limitation of radar receiver model).

2.4.3 Antenna

Assumption #1: If no radar receiver antenna parameters are specified, assumes diameter of antenna is 75% of the missile longitudinal reference dimension (assumed to be equal to the missile diameter), and wavelength is assumed to be 0.0166m (18 GHz). If no illuminator antenna parameters specified, illuminator antenna diameter is assumed to be 1.0m.

Documentation Reference: SUM page 6-51

Implications For Model Use: User should be aware of the default values if no antenna parameters are input.

Assumption #2: Unless a specific beam pattern is entered (i.e. tabular data) for either the receiver or illuminator antenna, a generic antenna pattern is chosen to provide closest match to the input data.

Documentation Reference: SUM page 6-52.

Implications For Model Use: User should be aware that an antenna pattern will be chosen. If the user does not like the choice then the input data should be altered to include a specific beam pattern.

2.4.4 Signal Processing

Assumption #1: Receiver signal processing uses a power-based approach not a waveform-level approach.

Documentation Reference: SUM, Appendix E, MSLRDR-1.

Implications For Model Use: Self explanatory (limitation of level of fidelity of model).

Assumption #2: AGC uses either a fixed dynamic range or is set based on the total power received (i.e. power entering the receiver before Doppler processing). In the latter case, the position of the set-point is subject to a specified maximum rate of change and uses upper and lower limits set to specified amounts above and below the set-point (although the lower limit is never allowed to be lower than a level that would place the AGC limit at the noise power level). Same for all radar seekers.

Documentation Reference: SUM pages 6-57 and 6-59, SUM page 6-68, SUM page 6-70.

Implications For Model Use: Allows a choice of two representative, 'perfect' AGC implementations. Model is not appropriate for the investigation of ECM effects.

Assumption #3: Cross-axis coupling can arise from a number of sources (mechanical, electrical, optical) and can occur at many places in the signal path. All the sources of cross-coupling are assumed to be represented by two user-specified, constant values which are the proportion of the command from each axis that will appear in the other axis.

Documentation Reference: SUM page 6-76.

Implications For Model Use: Provides a simple means of modeling the gross effects of cross-axis coupling.

Assumption #4: Bias drifts are uncommanded torques that are applied to the seeker platform (i.e. they have not been generated as a result of a change in the line-of-sight error signal). All sources of uncommanded torques are assumed to be represented by user-specified, constant drift rates in each of the seeker planes.

Documentation Reference: SUM page 6-76.

Implications For Model Use: Provides a simple means of modeling the gross effects of bias drifts.

2.4.5 Target Tracking

Assumption #1: It is assumed that the receiver will always center the Doppler window on the power-weighted Doppler frequency gate (subject to specified maximum rate of change and Doppler shift polarity, although since reference Doppler is zero, the Doppler shift polarity is meaningless), even if there is insufficient signal-to-noise ratio for angle tracking. Doppler bins are used for diagnostic purposes only, not part of the signal processing. Same for all radar seekers.

Documentation Reference: SUM pages 6-57 and 6-58, SUM page 6-69.

Implications For Model Use: Uses a ‘perfect’ Doppler tracker with only a rate limit applied. Model is not appropriate for investigation of ECM techniques.

Assumption #2: The Doppler value associated with each source is assumed to be the true Doppler of the signal along the appropriate path. This always includes the direct signals. If the multipath option is selected, the Doppler of the ground-reflected signal from each source is also considered, as well as both round-trip paths for the illuminator signal. If the clutter option is selected, the Doppler content of the clutter signal from each source is also considered.

Documentation Reference: SUM pages 6-56 to 6-58, 6-63 to 6-66, SUM page 6-69.

Implications For Model Use: Allows the user some control over the signal environment.

Assumption #3: Seeker is assumed to be able to angle track if the ‘sum’ power (in the Doppler gate and after AGC limiting) from the four monopulse beams is greater than the lower limit of the AGC dynamic range multiplied by the signal-to-noise ratio required to track. If insufficient signal-to-noise ratio, it is assumed that the line-of-sight tracking errors will be zero (i.e. no steering command generated). Same for all radar seekers.

Documentation Reference: SUM page 6-59, SUM page 6-67, SUM page 6-70.

Implications For Model Use: Uses a signal-to-noise criterion consistent with the level of fidelity in the rest of the power based received model.

Assumption #4: Line-of-sight tracking errors are obtained from differencing the power received in the four separate monopulse beams. Same for all radar seekers.

Documentation Reference: SUM page 6-59, SUM page 6-67, SUM page 6-70.

Implications For Model Use: Uses an approach consistent with the level of fidelity in the rest of the power based receiver model.

Assumption #5: There are no signal strength calculations for the generic seeker. It is always assumed to be locked on if the range to the target is less than a user-specified lock-on range.

Documentation Reference: SUM page 6-70.

Implications For Model Use: Allows a missile flyout to be performed without the need to consider target signature.

Assumption #6: Perfect Seeker - The platform motion of the perfect-seeker assumes that the seeker axis is always pointed at target with user specified bias angles added as appropriate. Seeker pointing is also subject to the gimbal angle limits (note however, that even if the perfect seeker is on the gimbal limits it does not affect the generation of the seeker guidance commands). Any signal strength checks and tracking errors from IR or radar seeker will not be used in the seeker platform motion or generation of guidance commands.

Documentation Reference: SUM page 6-72.

Implications For Model Use: Gives the best performance that could be expected from a seeker platform (instantaneous response). Because the seeker pointing is subject to gimbal angle limits, the user is made aware of the fact that the gimbal limit has been reached. Although these limits do not affect the generation of the guidance commands (based on the true line-of-sight rate), it indicates that a real missile may encounter seeker look angle constraints.

Assumption #7: Perfect Seeker With Filter - The platform motion of the perfect seeker with filter is identical to the platform motion of the perfect seeker. The filter is only applied to the line-of-sight rate used in the generation of the guidance commands.

Documentation Reference: SUM page 6-72.

Implications For Model Use: Same as for the perfect seeker.

Assumption #8: The momentum stabilized platform is assumed to act as a free gyro which responds to torques applied about one axis by precessing about an axis orthogonal to the plane containing the spin vector and the torque vector. The torques that are applied are assumed to come from the gimbal angle rate commands and the gimbal friction (due to the body axes rotational rates).

Documentation Reference: SUM page 6-73.

Implications For Model Use: Allows for representative motion of the seeker platform and hence the generation of guidance commands (based on the line-of-sight errors). However, since the seeker pointing (and hence the generation of guidance commands) is now affected by gimbal angle limits, it is essential that this model be coupled with a representative model of the airframe dynamics.

Assumption #9: For the momentum stabilized seeker platform, the update of the reference-axes to seeker-axes transformation matrix make the assumption of constant seeker platform rotational rates.

Documentation Reference: SUM page 6-119.

Implications For Model Use: Consistent with the assumption used to model the momentum stabilized platform.

Assumption #10: When any gimbal hits a limit, the constrained seeker axis will reflect the missile body-axes rates resolved into its axis. The unconstrained seeker-axis will drive into its stop at maximum gimbal rate. With both gimbals against their limits, subsequent motion of the seeker will simply reflect the body-axes rates resolved into seeker axes.

Documentation Reference: SUM page 6-73.

Implications For Model Use: Since the seeker pointing (and hence the generation of guidance commands) is now affected by gimbal angle limits, it is essential that this model be coupled with a representative model of the airframe dynamics.

Assumption #11: For a rate-stabilized seeker, if the gimbal moments-of-inertia are input as zero, they are calculated based on the seeker mass and the missile longitudinal reference dimension (assumed to be equal to the missile diameter).

Documentation Reference: SUM page 6-48.

Implications For Model Use: Allows this option to be used without the user having to calculate the seeker platform moments-of-inertia, but the resulting values may not accurately represent the actual platform.

Assumption #12: When any gimbal hits a limit, the gimbal angle is held constant and the platform rates and accelerations are simply the values for the missile body-axes resolved into the seeker axes.

Documentation Reference: SUM page 6-74.

Implications For Model Use: Since the seeker pointing (and hence the generation of guidance commands) is now affected by gimbal angle limits, it is essential that this model be coupled with a representative model of the airframe dynamics.

Assumption #13: It is assumed that error sources will only have an effect on the guidance commands produced by the seeker if a “real” seeker is being modeled.

Documentation Reference: SUM page 6-74.

Implications For Model Use: To model error sources the “real” seeker option must be chosen. This is the only option that uses the line-of-sight errors to generate the line-of-sight rate commands - the “perfect” and “perfect with filter” seeker options use the true line-of-sight rate (unfiltered and filtered, respectively) in the generation of their guidance commands.

Assumption #14: It is assumed that all of the effects of line-of-sight noise are combined in the user-specified values of horizontal and vertical look angle biases in seeker axes. These biases, which are added to the (true) geometric line-of-sight errors, are assumed to be constant and have the effect of shifting the aim point relative to the target. These biases only have an effect if an IR or generic seeker is being modeled. For the radar seekers, the line-of-sight tracking errors are calculated from the received power entering the receiver from all sources of power in the engagement. Note that line-of-sight noise can be introduced into the pointing of a “perfect” or a “perfect with filter” seeker if the type of seeker being modeled is either IR or generic, but will not be used in the generation of the line-of-sight guidance commands.

Documentation Reference: SUM page 6-74.

Implications For Model Use: Only applicable to an IR or generic seeker model.

<u>Assumption #15</u>: The effect of variations in the gains in the seeker track loop from all sources is assumed to be modeled by a single scale factor.

Documentation Reference: SUM page 6-75.

Implications For Model Use: Provides a simple means of modeling the gross sensitivity of the seeker track loop to gain variation.

3.0 WEAPONS

3.1 Warhead

<u>Assumption #1</u>: Successful flyout if PCA is within the input lethal radius.

Documentation Reference: SUM page 2-4.

Implications For Model Use: Fuze and warhead effects are not modeled.

6.0 DME

6.1 Guidance

<u>Assumption #1</u>: The non-reactive guidance schemes do not require the presence of a target, whereas, the reactive schemes generate guidance commands based on the motion of a target.

Documentation Reference: SUM pages 6-78 to 6-82.

Implications For Model Use: User should be aware that target modeling is not always necessary.

<u>Assumption #2</u>: For all the guidance options, it is assumed that the missile remains at zero body roll angle throughout its flight.

Documentation Reference: SUM page 6-78.

Implications For Model Use: Guidance commands are always generated in vertical and horizontal planes. It may not be possible to represent a specific type of guidance (e.g. one that relies on a bank-to-turn airframe).

Projected Corrections or Changes: Arbitrary body roll angles are now accommodated in TRAP 4.0.

Assumption #3: Pre-programmed guidance assumes that the missile will generate a lateral acceleration normal to the flight path to match altitude-vs.-time and crossrange-vs.-time profiles input by the user.

Documentation Reference: SUM page 6-80.

Implications For Model Use: Self explanatory (limitation of the selected guidance scheme).

Assumption #4: Constant altitude guidance assumes that the missile will generate a lateral acceleration in the vertical plane in order to keep the missile at a user-specified constant altitude. Hard-wired gains are used in the altitude control algorithm.

Documentation Reference: SUM page 6-80, Appendix E, CONALT-3, block (3).

Implications For Model Use: Self explanatory (limitation of the selected guidance scheme).

Assumption #5: Constant flight-path angle guidance assumes the missile will generate a lateral acceleration normal to the flight path to maintain the missile on a constant flight-path angle, which is aligned with the missile flight-path angles at launch time. Hard-wired gains are used in the algorithm to control the flight-path angle. To fly the specified flight-path angle in pitch, the missile must be launched on a heading of zero and remain on that heading throughout. To fly the specified flight-path angle in azimuth, the missile must be launched on a heading between -90 and 90 degrees, and headings close to ± 90 degrees should be avoided.

Documentation Reference: SUM page 6-81, Appendix E, CONANP-3, blocks (1), (4) and (6), CONANY-3, blocks (1) and (6).

Implications For Model Use: Self explanatory (limitation of the selected guidance scheme).

Assumption #6: Constant ‘g’ guidance assumes that the missile will execute a specified number of flyouts, with each flyout generating a different value of constant lateral acceleration command in either pitch or yaw.

Documentation Reference: SUM page 6-82.

Implications For Model Use: Self explanatory (limitation of the selected guidance scheme).

Assumption #7: Pseudo kinematic link (PKL) guidance assumes that the missile uses a semi-active radar seeker.

Documentation Reference: SUM page 6-79.

Implications For Model Use: Self explanatory (limitation of the selected guidance scheme).

Assumption #8: Pseudo-kinematic link (PKL) guidance assumes that the missile will generate a lateral acceleration command.

Documentation Reference: SUM page 6-79.

Implications For Model Use: Self explanatory (limitation of the selected guidance scheme).

Assumption #9: Proportional navigation guidance (rate) assumes that the missile will generate a flight-path turning rate demand.

Documentation Reference: SUM page 6-79.

Implications For Model Use: Self explanatory (limitation of the selected guidance scheme).

Assumption #10: Proportional navigation guidance (acceleration) assumes that the missile will generate a lateral acceleration command normal to the flight path.

Documentation Reference: SUM page 6-80.

Implications For Model Use: Self explanatory (limitation of the selected guidance scheme).

Assumption #11: Proportional navigation guidance (acceleration) assumes that missile-to-target closing velocity is known.

Documentation Reference: SUM page 6-80.

Implications For Model Use: If the real missile does not measure closing velocity, then code should be written to model the algorithm that the missile uses to estimate closing velocity.

Assumption #12: Pursuit and deviated pursuit guidance both assume that the missile will generate a lateral acceleration command normal to the flight path.

Documentation Reference: SUM page 6-81.

Implications For Model Use: Self explanatory (limitation of the selected guidance scheme).

Assumption #13: Pursuit and deviated pursuit guidance both assume that the missile-to-target closing velocity is known.

Documentation Reference: SUM page 6-81.

Implications For Model Use: If the real missile does not measure closing velocity, then code should be written to model the algorithm that the missile uses to estimate closing velocity.

Assumption #14: For deviated pursuit guidance it is assumed that the user-input values for the pitch and yaw lead angle biases are of the correct sign which reflects the geometry of the intercept.

Documentation Reference: SUM, Appendix E, PURSTP-3, block (1) and PURSTY-3, block(2).

Implications For Model Use: It is up to the user to make sure that the correct sign has been assigned to the input values of the lead-angle biases. Particular care should be taken when executing multiple runs (for instance when generating launch zone boundaries).

Assumption #15: Perfect Seeker - Provided the seeker has not lost lock (based on signal to noise calculations), the seeker line-of-sight rate commands are set to the true inertial line-of-sight rate resolved into vertical and horizontal components in body axes limited by the user-input maximum line-of-sight tracking rate. Note that even if the line-of-sight to the target places the perfect seeker beyond its gimbal limits, the true line-of sight rate is still used. Note that even if the seeker has broken lock, the line-of-sight rate commands are only set to zero if break-lock action was specified as zero output.

Documentation Reference: SUM page 6-70.

Implications For Model Use: Allows for the generation of missile guidance commands without the need to develop a detailed model of the seeker platform. This 'no lag' model indicates the best performance that could be expected from a seeker platform. Because the true line-of-sight rate is always used (even if beyond the gimbal limits), it allows for the continuous generation of guidance commands when the airframe dynamics are not known with any certainty and would have otherwise lead to a gimbal limit being reached because the body attitude was unrepresentative of the real missile in the same situation (e.g. when using a point-mass airframe model).

Assumption #16: Perfect Seeker with Filter - The perfect seeker with filter is modeled in an identical way to the perfect seeker, except that the line-of-sight rate commands are generated from filtering the true line-of-sight rate after it has been resolved into vertical and horizontal components in body axes.

Documentation Reference: SUM page 6-71.

Implications For Model Use: Allows the perfect seeker model to generate more realistic missile guidance commands while still avoiding the need to develop a detailed model of the seeker platform.

Assumption #17: For a real seeker, the line-of-sight rate commands are generated by multiplying the line-of-sight error by a user input gain (this also includes a bias-factor). The line-of sight errors are already in seeker axes. The line-of-sight rate commands are limited by the user-input maximum line-of-sight tracking rate. Note that even if the seeker has broken lock, the line-of-sight rate commands are only set to zero if break-lock action was specified as zero output (except for a radar seeker if the signal to noise ratio is insufficient for lock-on then the line-of-sight errors will have been set to zero, hence the line-of-sight rate commands will also be zero). Note that for both IR and generic seekers the line-of-sight errors are simply the geometric line-of-sight errors between the seeker x-axis and the line-of-sight to the target (with user-specified bias angles if appropriate), while for radar seekers, the line-of-sight errors are the tracking errors output from the missile radar model.

Documentation Reference: SUM page 6-71.

Implications For Model Use: If the data are available to support a detailed seeker platform model, allows representative missile guidance commands to be generated based on the line-of-sight errors built up while the seeker tries to track the target.

6.2 Autopilot

Assumption #1: It is assumed that the user has selected appropriate gains such that when the guidance commands are limited by the autopilot controller they are in the form of accelerations.

Documentation Reference: SUM page 6-85.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case user must be aware of the required units throughout the guidance, autopilot and control chain.

Assumption #2: It is assumed that, when the input to the autopilot is in one set of units, and the output to the control system is in another set of units, the user has selected appropriate gains such that the units of the output are consistent with the control system being modeled. This includes consistency of units for commands produced by the outer loop of an autopilot for implementation by the inner loop.

Documentation Reference: SUM pages 6-86, 6-87, 6-88, 6-89.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case user must be aware of the required units throughout the guidance, autopilot and control chain.

Assumption #3: For point-mass simulations, it is assumed that an autopilot and control system exist that will produce the lateral acceleration demanded by the guidance system up to user-specified limits, subject only to a maximum rate of change of the missile AOA (modeled in the point-mass aerodynamics).

Documentation Reference: SUM page 6-85.

Implications For Model Use: Self explanatory, user should be aware of the limits being applied.

Assumption #4: For 6-DOF simulations, it is assumed that the roll control autopilot controls the missile to zero body roll angle (this is consistent with the assumption that all missiles in TRAP remain at zero body roll angle throughout their flight).

Documentation Reference: SUM page 6-86.

Implications For Model Use: Self explanatory (limitation of model).

Projected Corrections or Changes: TRAP 4.0 now supports several control options that allow for non-zero body roll angles.

Assumption #5: For the fin-position control autopilot it is assumed that the input, generated by the autopilot controller, is the angular deflection required for the control surface. The output of the autopilot is a control surface deflection command.

Documentation Reference: SUM 6-86.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case user must be aware of the required units throughout the guidance, autopilot and control chain.

Assumption #6: For the torque-balance control autopilot it is assumed that the input, generated by the autopilot controller, is the actuator torque required for the control surface. The output from the autopilot is an actuator torque command.

Documentation Reference: SUM page 6-86.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case the user must be aware of the required units throughout the guidance, autopilot and control chain.

Assumption #7: The single rate gyro autopilot assumes that the input, generated by the autopilot controller or an outer loop of the autopilot, is the required body rate. The output from the autopilot is a control surface deflection command.

Documentation Reference: SUM page 6-86.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case the user must be aware of the required units throughout the guidance, autopilot and control chain.

Assumption #8: The body-attitude autopilot with one rate gyro assumes that the input, generated by the autopilot controller, is a body attitude command.

Documentation Reference: SUM page 6-87.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case user must be aware of the required units throughout the guidance, autopilot and control chain.

Assumption #9: The body-attitude autopilot with one rate gyro assumes that the output from the outer loop (body-attitude loop) is a body rate command for implementation in the inner loop (single rate gyro autopilot) which produces a control surface deflection command.

Documentation Reference: SUM page 6-87.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case user must be aware of the required units throughout the guidance, autopilot and control chain.

Assumption #10: The autopilot, using one accelerometer and one rate gyro assumes, that the input generated by the autopilot controller is a body acceleration command.

Documentation Reference: SUM page 6-87.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case user must be aware of the required units throughout the guidance, autopilot and control chain.

Assumption #11: The autopilot with one accelerometer and one rate gyro, assumes that the output from the outer loop (body-acceleration loop) is a body rate command for implementation in the inner loop (single rate gyro autopilot), which produces a control surface deflection command.

Documentation Reference: SUM page 6-87.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case user must be aware of the required units throughout the guidance, autopilot and control chain.

Assumption #12: The autopilot, using two accelerometers, assumes that the input generated by the autopilot controller is a body acceleration command.

Documentation Reference: SUM page 6-87.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case user must be aware of the required units throughout the guidance, autopilot and control chain.

Assumption #13: The autopilot with two accelerometers assumes that the output from the outer loop (midship mounted accelerometer loop) is also a body acceleration command for implementation in the inner loop (forward mounted accelerometer autopilot). The output of the inner accelerometer loop is a control surface deflection command.

Documentation Reference: SUM page 6-88.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case user must be aware of the required units throughout the guidance, autopilot and control chain.

Assumption #14: The synthetic stability autopilot assumes that the input, generated by the autopilot controller, is a body acceleration command.

Documentation Reference: SUM page 6-88.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case user must be aware of the required units throughout the guidance, autopilot and control chain.

Assumption #15: The synthetic stability autopilot assumes that the output from the outer loop (body acceleration loop) is a body rate command for implementation in the inner loop (body-rate loop). The output of the inner body-rate loop is a control surface deflection command.

Documentation Reference: SUM page 6-89.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case user must be aware of the required units throughout the guidance, autopilot and control chain.

Assumption #16: The AOA autopilot with one rate gyro assumes that the input, generated by the autopilot controller, is an AOA command.

Documentation Reference: SUM page 6-89.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case user must be aware of the required units throughout the guidance, autopilot and control chain.

Assumption #17: The AOA autopilot with one rate gyro assumes that the output from the outer loop (AOA loop) is a body rate command for implementation in the inner loop (single rate gyro autopilot) which produces a control surface deflection command.

Documentation Reference: SUM page 6-89.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case user must be aware of the required units throughout the guidance, autopilot and control chain.

Assumption #18: The pitch and yaw commands from the autopilot are assumed to be for a '+'-configuration missile unless the synthetic stability autopilot is being used (in which case they will be for an 'x'-configuration missile).

Documentation Reference: SUM page 6-90.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case user must be aware of the convention being used.

Assumption #19: If the synthetic stability autopilot has been selected, a tail controlled missile is assumed with control demands generated in the 'x'-configuration.

Documentation Reference: SUM pages 6-90 and 6-92.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case user must be aware of the convention being used.

Assumption #20: For the ‘+’-configuration, the control surfaces are deflected in pairs, one pair of diametrically opposite surfaces for the pitch command and the other pair for yaw. The control surface deflections for roll are applied equally to four control surfaces (location of the control surfaces is not specified), independently of the pitch and yaw commands.

Documentation Reference: SUM pages 6-90 and 6-91.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case user must be aware of the convention being used.

Projected Corrections or Changes: May be changed as a result of planned enhancements to the aerodynamic methodology.

Assumption #21: For the ‘x’ configuration, if the synthetic stability autopilot is NOT being used, one set of four control surfaces handles all the control demands in pitch, yaw and roll. The pitch and yaw commands are resolved from the ‘+’-configuration into separate commands for each of the control surface actuators. If the synthetic stability autopilot is being used, the commands are already for an ‘x’-configuration and do not need to be resolved.

Documentation Reference: SUM pages 6-91 and 6-92.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case user must be aware of the convention being used.

Projected Corrections or Changes: May be changed as a result of planned enhancements to the aerodynamic methodology.

Assumption #22: When TVC is used, the pitch and yaw commands from the autopilot are assumed to be for a ‘+’ configuration.

Documentation Reference: SUM pages 6-89 and 6-90.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case user must be aware of the convention being used.

Assumption #23: If the TVC option is selected (by setting the type of autopilot, TYPAPP and TYPAPY to THRUST-VECT) then it is assumed that the missile uses a body-attitude autopilot with one rate gyro.

Documentation Reference: SUM pages 6-87, 6-90.

Implications For Model Use: None, unless the user is developing a new or modified missile system.

Projected Corrections or Changes: Allowing a wider range of autopilot types for a TVC missile may make system development easier.

IV ENVIRONMENT

1.1 Atmospheric Attenuation

Assumption #1: The differential absorption coefficients (dB/km) for oxygen and water vapor are each assumed to be constant values (user-input).

Documentation Reference: SUM, Appendix E, PPLOSS-1, block (1).

Implications For Model Use: User must choose values appropriate for the conditions of the intercept.

Implications For Model Use: Self explanatory (limitation of fidelity of the model).

Assumption #2: Absorption coefficients assume a horizontal path at sea level (provides pessimistic estimate of absorption coefficients at higher altitudes) due to O_2 and H_2O only, and a temperature of 20 degrees Celsius. Clear weather conditions are assumed (no rain, clouds or fog). Calculations are performed once during initialization. Atmospheric losses at frequencies less than 3 GHz are very small and are set to the 3 GHz value (which is pessimistic for these lower frequencies). Same for all radar seekers.

Documentation Reference: SUM page 6-52.

Implications For Model Use: Self explanatory (limitation of fidelity of the model).

Assumption #3: Atmospheric properties are assumed to be represented by a model of a standard atmosphere (note: actual atmosphere is not specified; even in TRAP 3.0 code and User's Manual, no particular atmosphere was specified). Uses a curve fit to properties in English units but returns values in metric units.

Documentation Reference: SUM page 6-119.

Implications For Model Use: If missile performance in a non-standard (e.g. hot or cold) atmosphere is required, the code would have to be modified to include a correction for the non-standard conditions.

1.3 Radiance/Transmittance

Assumption #1: Currently the calls to the atmospheric transmission tables are bypassed and the transmittance is set to 1 (no attenuation).

Documentation Reference: SUM, Appendix E, IRSNR-4, blocks (3) and (4).

Implications For Model Use: Optimistic lock-on ranges will be obtained.

Projected Corrections or Changes: The atmospheric transmission tables should be implemented.

2.0 Topographic

Assumption #1: Calculation of the maximum line-of-sight assumes the path is over a curved Earth (with zero altitude terrain).

Documentation Reference: SUM page 6-34.

Implications For Model Use: Self explanatory.

Projected Corrections or Changes: The whole of the AI radar modeling is due to be revisited.

2.1 Clutter

Assumption #1: Models a diffuse reflection from an illuminated ground surface (specular reflection components are accommodated by the multipath model). Ground surface reflection coefficients are calculated for the appropriate type of terrain selected from a list of terrain types. The list of terrain types is consistent with those used for the multipath calculations. Derived from Volume II of the Radar Cross Section Handbook (G. T. Ruck, Plenum Press, 1970). Same for all radar seekers.

Documentation Reference: SUM page 6-66, Appendix E, RFLCTC-6.

Implications For Model Use: Because of the diffuse scattering from the many possible ground scatterers, no attempt is made to model polarization effects. Average cross section values are calculated that are frequency, terrain/surface and aspect dependent.

Assumption #2: It is assumed that all of the emitter power (mainbeam and sidelobes) falling on the projection of the receiver mainbeam onto the ground will reach the receiver.

Documentation Reference: SUM page 6-66.

Implications For Model Use: No clutter power from the emitter will be received through the receiver sidelobes. Consistent with other assumptions in the clutter and multipath models about secondary sources of power.

Assumption #3: It is assumed that the power from the illuminator sidelobes that is reflected into the receiver sidelobes is negligible. However, the illuminator mainbeam power projected onto the ground is assumed to reach the receiver through either the mainbeam or the sidelobes. Note that if the same antenna is used for the illuminator and receiver, then the illuminator and receiver mainbeam ground clutter patches will be identical, and clutter processing is automatically applied only to the mainbeam (everything else is illuminator sidelobe to receiver sidelobe).

Documentation Reference: SUM page 6-66 (semi-active), SUM page 6-69 (active).

Implications For Model Use. Consistent with other assumptions in the clutter and multipath models about secondary sources of power.

2.2 Multipath/Diffraction

Assumption #1: Multipath reflection losses are calculated via Fresnel coefficients for the appropriate type of terrain selected from a list of terrain types. Includes the effects of polarization. Same for all radar seekers.

Documentation Reference: SUM page 6-57, SUM pages 6-63 to 6-65.

Implications For Model Use: Consistent with the level of fidelity for the modeling of clutter.

Assumption #2: For the target signal, the paths considered are direct illumination of target with reflected return, and indirect (reflected) illumination of target with direct return. Reflected illumination of target with reflected return is not considered. For both the direct and indirect illumination of the target, the RCS is calculated from a viewing aspect that is midway between the lines-of-sight of the incident and reflected paths. Active and semi-active radar seeker.

Documentation Reference: SUM page 6-69, SUM pages 6-63 to 6-66.

Implications For Model Use: Considers major contributing paths for the reflected power. Neglecting the path of reflected illumination and reflected return is consistent with the approach of neglecting the sidelobe contributions in the clutter calculations. Use of the viewing aspect midway between the lines-of-sight of the incident and reflected paths allows for a monostatic RCS table to be used which is considerably smaller than a bistatic table, but at the loss of some fidelity.

GENERAL

Assumption #1: It is assumed that the general integration of state variables is adequately represented by the use of a second order Adams-Bashforth predictor.

Documentation Reference: SUM page 6-120.

Implications For Model Use: None. This approach has been found to be accurate enough for the fidelity of the modeling without imposing an excessive computational burden on the model.

Assumption #2: It is assumed that the integration of transfer functions is adequately described by use of the Tustin approximation. Currently, this includes most of the standard transfer functions up to and including second order lags.

Documentation Reference: SUM page 6-120.

Implications For Model Use: None, unless the user is developing a new or modified model, in which case the user should note the limiting values of the time constants and natural frequencies in comparison to the simulation time step. If the time constants are too small or the natural frequencies too high (when compared to the simulation time step), then the method degenerates. The user should then replace the transfer function with a pure gain (i.e. the process being modeled happens so quickly compared to other events in the simulation that it can be treated as happening instantaneously), or the simulation should be run with a smaller time step.

Assumption #3: If rotational accelerations are not known, it is assumed that direction cosine matrices (transformation matrices) can be adequately updated using an exact analytic solution with the assumption of constant angular rates.

Documentation Reference: SUM page 6-119.

Implications For Model Use: None. This approach has been found to be accurate enough for the fidelity of the modeling without imposing an excessive computational burden on the model.

Assumption #4: If rotational accelerations are known, then it is assumed that the direction cosine matrices (transformation matrices) can be adequately updated using a second-order Taylor series expansion.

Documentation Reference: SUM page 6-119.

Implications For Model Use: None. This approach has been found to be accurate enough for the fidelity of the modeling without imposing an excessive computational burden on the model.

Assumption #5: When generating launch zone boundaries with the smart search option, whenever a boundary point is found, a limit is placed on the launch range for subsequent launch aspects.

Documentation Reference: SUM, Appendix E, LARBND-5, block (3) and LARBND-6, block (4) and LARBND-9, block (17).

Implications For Model Use: When searching for an inner boundary, the search should commence at the launch aspect that provides the smallest minimum range. When searching for an outer boundary the search should commence at the launch aspect that provides the largest maximum launch range.

Projected Corrections or Changes: The methodology for the generation of launch zones is due to be reviewed.

Coordinate Frames and Transformations

Assumption #1: A right handed reference (Earth) axes system is used with the x-axis positive North, y-axis positive East and z-axis positive down. The z-axis origin is at the surface of the Earth. All measurements that are defined as altitudes are positive up.

Documentation Reference: SUM, Appendix A, page A-1.

Implications For Model Use: Self explanatory.

Assumption #2: The location of any vehicle in the reference frame is measured from the origin of the reference axes to the center-of-gravity of the vehicle.

Documentation Reference: SUM, Appendix A, page A-2.

Implications For Model Use: Self explanatory.

Assumption #3: For any vehicle, the body x-axis is positive forward, y-axis is positive to starboard, and the z-axis is positive down, with origin at the center-of-gravity of the vehicle. Note, however, that some variables for the missile are measured backwards (i.e. in the negative x-direction) from the nose of the missile, but this is usually for the convenience of user-input.

Documentation Reference: SUM, Appendix A, page A-2.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case care must be taken to ensure that all variables relating to the body axis system are of the correct sign.

Assumption #4: The Euler angles used in TRAP assume the rotation sequence azimuth (yaw), followed by elevation (pitch), followed by roll, when moving from the reference frame to any other frame. Each angle is positive clockwise when looking along the axis of rotation.

Documentation Reference: SUM, Appendix A, page A-8.

Implications For Model Use: Self explanatory.

Assumption #5: The transformation from body-axes to flight-path axes assumes the rotation sequence AOA (tangent definition), followed by sideslip angle (sine definition). Positive AOA corresponds to a positive velocity along the body z-axis (i.e. relative wind from below), and positive sideslip angle corresponds to a positive velocity along the body y-axis (i.e. relative wind from starboard).

Documentation Reference: SUM, Appendix A, page A-10.

Implications For Model Use: Self explanatory.

Assumption #6: The seeker is assumed to be mounted on pitch and yaw gimbals (no roll gimbal is modeled since the body is always assumed to be at zero roll angle). Both inner-pitch and inner-yaw gimbal arrangements are allowed. The rotation from seeker reference to seeker axes is in the order outer gimbal followed by inner gimbal.

Documentation Reference: SUM, Appendix A, page A-12.

Implications For Model Use: Self explanatory.

LIMITATIONS

This section contains brief descriptions of the limitations that have been identified in TRAP 3.1a. This section addresses the known limitations identified in published sources or reported by model users and model developers. Other limitations may become apparent during subsequent phases of the model accreditation process.

The contents of this section are closely linked with the previous section on assumptions. Indeed, many of those assumptions imply some limitation on the use of the model. In such cases, the limitation is indicated under the heading of "Implications for Model Use" with the appropriate assumption and, in general, has not been repeated here. It is therefore recommended that the reader review the assumptions in the previous section before looking at the limitations identified in this section.

I TARGET

1.2 Movement

Limitation #1: The non-generic target is limited to the following pre-programmed maneuvers: change/maintain altitude, turn to a heading/continuous level turn, constant 'g' (combined plane), change speed, offset, s-turn, takeoff and landing.

Documentation Reference: SUM page 6-6.

Implications For Model Use: User must select from the range of existing maneuvers or generate new code to model the required maneuver.

Limitation #2: The generic target has a more limited set of maneuvers compared to a non-generic target. Maneuvers available are: change/maintain altitude, offset, and s-turn.

Documentation Reference: SUM page 6-6 and code comparison (TRAP 3.1a vs. TRAP 3.1).

Implications For Model Use: User must select from the range of existing maneuvers or generate new code to model the required maneuver.

Limitation #3: Both the generic and non-generic target are limited to the same number of reactive maneuvers. The maneuvers available are: pursuit, level beam, slice, level drag and descending drag.

Documentation Reference: SUM 6-6 and code comparison (TRAP 3.1a vs. TRAP 3.1).

Implications For Model Use: User must select from the range of existing maneuvers or generate new code to model the required maneuver.

5.0 CM/CCM

5.1.1 On-board Jammer

Limitation #1: Airborne jammers (one carried by each of the targets) may only be used if the missile has a semi-active or active radar seeker.

Documentation Reference: SUM pages 6-56, 6-59 and 6-68.

Implications For Model Use: Cannot use an airborne jammer as the target for a passive radar seeker.

Limitation #2: Only one radar jammer per target aircraft is permitted (for a maximum of two target aircraft).

Documentation Reference: SUM pages 6-59 and 6-68.

Implications For Model Use: Self explanatory.

Limitation #3: If two jammers are modeled (one on each target), they must both have the same beam pattern.

Documentation Reference: SUM page 6-60 and 6-68.

Implications For Model Use: Self explanatory.

5.1.3 Standoff Jammer

Limitation #1: Off-board (ground-based) jammers may only be used if the missile has a passive radar seeker.

Documentation Reference: SUM pages 6-56, 6-59 and 6-68.

Implications For Model Use: Cannot have ground-based jammers as part of an air-to-air engagement with semi-active radar or active radar seekers.

Limitation #2: A maximum of 10 ground-based jammers is allowed.

Documentation Reference: SUM page 6-56.

Implications For Model Use: Self explanatory.

II LAUNCH PLATFORM

1.2 Movement

Limitation #1: The launch aircraft can be "aimed" at the target only at the start of the simulation. The "aiming" is directed towards the primary target only.

Documentation Reference: SUM, Appendix E, STKDRN-3, block(20 and TRAP-3, block (10).

Implications For Model Use: Self explanatory.

Limitation #2: The non-generic launch aircraft is limited to the following pre-programmed maneuvers: change/maintain altitude, continuous level turn, constant 'g' (combined plane), offset.

Documentation Reference: SUM page 6-25.

Implications For Model Use: User must select from the range of existing maneuvers or generate new code to model the required maneuver.

Limitation #3: The generic launch aircraft has a more limited set of maneuvers compared to a non-generic launch aircraft. Maneuvers available are: change/maintain altitude and offset.

Documentation Reference: SUM page 6-25 and code comparison (TRAP 3.1a vs. TRAP 3.1).

Implications For Model Use: User must select from the range of existing maneuvers or generate new code to model the required maneuver.

Projected Corrections or Changes: None

Limitation #4: Both the generic and non-generic target are limited to a single reactive maneuver. The one reactive maneuver available is pursuit of the target.

Documentation Reference: SUM 6-25 and code comparison (TRAP 3.1a vs. TRAP 3.1).

Implications For Model Use: User must select from the range of existing maneuvers or generate new code to model the required maneuver.

2.0 SENSORS

2.4 RF (AI Radar)

Limitation #1: The “realistic” AI radar has not been fully exercised in TRAP (although it was fully checked out in a stand-alone version prior to integration with TRAP).

Documentation Reference: SUM page 6-33.

Implications For Model Use: Currently, it is recommended that the AI radar model is not used.

Projected Corrections or Changes: The whole of the AI radar modeling is due to be reviewed.

2.4.4 Signal Processing

Limitation #1: The AI radar tries to acquire only the primary target.

Documentation Reference: SUM page 6-33.

Implications For Model Use: AI radar model was developed when only one target was modeled. AI radar will not be aware of second target.

Projected Corrections or Changes: The whole of the AI radar modeling is due to be reviewed.

2.4.5 Target Tracking

Limitation #1: The AI radar only tries to track the primary target.

Documentation Reference: SUM page 6-33.

Implications For Model Use: AI radar model was developed when only one target was modeled. AI radar will not be aware of second target.

Projected Corrections or Changes: The whole of the AI radar modeling is due to be reviewed.

III MISSILE

1.2 Movement

1.2.1 Propulsion

Limitation #1: A maximum of two separate propulsion stages are allowed for the missile.

Documentation Reference: SUM page 6-40.

Implications For Model Use: None, unless the user is developing a new or modified missile model, in which case system specific code would have to be written.

Limitation #2: Thrust vector control is not modeled for the point-mass missile.

Documentation Reference: SUM page 6-106 and Appendix E, PMISEQ-1.

Implications For Model Use: Self explanatory.

Projected Corrections or Changes: During the planned enhancements to the aerodynamic methodology, it is intended to add the capability to model a TVC missile at the point-mass level.

1.2.2 Aerodynamics/Kinematics

Limitation #1: Launch transients, such as lateral missile acceleration due to ejection, or missile flight through aircraft flowfield, are not modeled.

Documentation Reference: SUM pages 6-37.

Implications For Model Use: None, provided that the missile is launched within accepted launch constraints for the particular launch aircraft and missile combination, it is assumed that these effects can be handled adequately by the autopilot and control system of the real missile without a significant penalty being placed on the performance of the missile.

Limitation #2: Missile flight through the vertical is prohibited.

Documentation Reference: SUM page 2-4.

Implications For Model Use: Places a limit on the intercept geometry that may be used.

Projected Corrections or Changes: Missile flight through the vertical is now possible in TRAP 4.0.

2.0 SENSORS

2.4 RF

2.4.3 Antenna

Limitation #1: If the antenna beam pattern is not described by tabular data, a limited number of beam patterns may be selected (from a list of options), or if one of these beam patterns is not specified, the program will choose the one from the list that most closely matches the other antenna parameters that were input. This applies to both the illuminator (semi-active and active radar seekers) and receiver (all radar seekers).

Documentation Reference: SUM pages 6-50 to 6-52.

Implications For Model Use: User should be aware how the lack of data input will influence the model and check that an appropriate beam pattern has been selected.

3.0 WEAPONS

3.1 Warhead

Limitation #1: No warhead or fuzing functions are modeled (a successful flyout is achieved if the missile passes within a specified distance of the center-of-gravity of the target).

Documentation Reference: SUM page 2-4.

Implications For Model Use: Cannot be used for detailed fuze and warhead studies.

6.0 DME

6.1 Guidance

Limitation #1: Only Cartesian (skid-to-turn) controlled missiles (with controls in the '+' or 'x' configuration) can be modeled, i.e. pitch and yaw commands are generated.

Documentation Reference: SUM pages 6-84 and 6-85.

Implications For Model Use: Cannot model a bank-to-turn missile.

Projected Corrections or Changes: Bank-to-turn missiles can be modeled in TRAP 4.0.

ERRORS

This section contains brief descriptions of the errors that have been identified in TRAP 3.1a. This section addresses the known errors identified in the available documentation or that have been identified and reported by model users and model developers. Other errors may become apparent during extensive model use and subsequent phases of the model accreditation process. There are some areas of the code that have not been exercised as much as others, for instance the radar seeker and the AI radar. Although some errors have been identified in these areas of the code, they have not been reported here because the documentation of those errors was insufficient to properly characterize the errors.

I TARGET

1.2 Movement

Error #1: The non-generic target is forced to have a zero flight-path angle in pitch no matter what the input value of the initial body pitch angle (this is because the body pitch angle is set equal to the AOA).

Documentation Reference: SUM, Appendix E, TGINIT-8, block(10).

Implications For Model Use: The target aircraft will always be initialized to level flight.

Projected Corrections or Changes: Rectified in TRAP 4.0; the initial pitch attitude of the target aircraft (INTHTG) is now interpreted as a flight-path pitch angle and the AOA is added to it to obtain the body pitch angle.

Error #2: For the non-generic target, once the roll-in to the commanded bank angle has been completed, an algorithm maintains the bank angle by demanding a roll acceleration based on the difference between the commanded and actual bank angle. However, the algorithm is in error as it does not include a feedback term based on the roll rate.

Documentation Reference: SUM, Appendix E, THEADG-21, block (28).

Implications For Model Use: In certain circumstances, particularly if the target aircraft is aerodynamically limited, the current algorithm for maintaining the bank angle can lead to an instability in roll.

Projected Corrections or Changes: A feedback term based on the roll rate should be included in the algorithm.

Error #3: For the non-generic target, the altitude control logic in the routine TSTURN, which controls the s-turn maneuver, is in conflict with the altitude control logic in the routine TGNALT (the routine TGNALT is called by the routine THEADG, which itself is called by TSTURN to control the target aircraft during the portions of turning flight in the s-turn maneuver).

Documentation Reference: SUM, Appendix E, TSTURN-5, block (6).

Implications For Model Use: If the input parameter LVLALT (desired altitude) is the same as the initial altitude of the target aircraft, the effect is simply to double the gain of the altitude control loop. However, if LVLALT is not the same as the initial altitude of the target aircraft, the target aircraft is likely to attain an altitude somewhere between the two.

Projected Corrections or Changes: Modify the altitude control algorithm in the routine TSTURN to overwrite the command for additional normal acceleration generated by the routine TGNALT (SUM, Appendix E, TSTURN-5, block (6)).

Error #4: For the non-generic target, there are inconsistencies between the logic in the routine TDDRAG, which controls the descending drag maneuver, and the routine TGNGEE which controls the target aircraft roll angle.

Documentation Reference: SUM, Appendix E, TDDRAG-10, block (9) and TDDRAG-11, blocks (13) and (14).

Implications For Model Use: This function will not operate correctly in some circumstances, but implications not evaluated.

Projected Corrections or Changes: Several modifications are needed (SUM, Appendix E, TDDRAG-10, block (9) and TDDRAG-11, blocks (13) and (14)).

1.3 Signature

1.3.2 IR

Error #1: The code uses the lines-of-sight from the missile-to-target instead of the lines-of-sight from the target-to-missile (in the same format as the IR signature data) when determining the aspect for looking up the target IR signature.

Documentation Reference: SUM, page 6-34 and Appendix E, IRSNR-2, block (2).

Implications For Model Use: The user should set a single value for the target IR in the POLICY routine (SUM page 6-34).

Projected Corrections or Changes: The correct aspect angles need to be calculated and substituted for the lines-of-sight from the missile-to-target.

1.3.3 RCS

Error #1: The code for the calculation of target RCS for the AI radar is currently commented out and no value is returned. In addition, the commented out code is in error, as it uses the lines-of-sight from the missile-to-target instead of the lines-of-sight from the target-to-launch aircraft (in the same format as the RCS data) when determining the aspect for looking up the RCS.

Documentation Reference: SUM, page 6-34 and Appendix E, ACSNR-2, block (1).

Implications For Model Use: The user should set a single value for the target RCS in the POLICY routine (SUM page 6-34).

Projected Corrections or Changes: The whole of the AI radar modeling is due to be revisited.

II LAUNCH AIRCRAFT

1.2 Movement

<u>Error #1</u>: Flight-path angles of the aircraft are calculated (THEACV and PSIACV in pitch and azimuth, respectively), but these are never used anywhere in the program. These calculations also equate mixed units (degrees and radians) and assume that the AOA is zero.

Documentation Reference: SUM, Appendix E, ACINIT-4, block (2) and ACINIT-8, block (2).

Implications For Model Use: None unless the user tries to use these variables in user-written code.

Projected Corrections or Changes: These calculations should be deleted.

<u>Error #2</u>: In TRAP 3.1 the non-generic launch aircraft is forced to have a zero flight-path angle in pitch no matter what the input value of the initial body pitch angle or the aiming of the launch aircraft in pitch (this is because the body pitch angle is set equal to the AOA). In going from TRAP 3.1 to TRAP 3.1a the AOA was removed from the calculation of the non-generic launch aircraft body attitude. This then set the body pitch angle equal to the flight-path pitch angle and the flight-path pitch angle was set to a value which was lower than it should have been by the aircraft angle-of attack.

Documentation Reference: SUM, Appendix E, ACINIT-6, block (10) and code comparison (TRAP 3.1a vs. TRAP 3.1).

Implications For Model Use: For the non-generic launch aircraft, the initialized values of both the body and the flight-path pitch angles will be too low by an amount equal to the AOA.

Projected Corrections or Changes: Rectified in TRAP 4.0, the initial pitch attitude of the aircraft (INTHAC) is now interpreted as a flight-path pitch angle, and the AOA is added to it to obtain the body pitch angle.

<u>Error #3</u>: For the change/maintain altitude maneuver, the flight-path roll acceleration is always set to zero. This is only an error in the sense that, if another routine controlling the turning flight calls this routine, the flight-path roll acceleration calculated in the other routine will be overwritten.

Documentation Reference: SUM, Appendix E, ACNALT-2, block(3).

Implications For Model Use: Possible error if user-written aircraft maneuver requires the routine ACNALT to control altitude during turning flight.

Projected Corrections or Changes: Modified in TRAP 4.0 so that flight-path roll acceleration is only set to zero if the maneuver is to change or maintain altitude.

2.0 SENSORS

2.4 RF (AI Radar)

2.4.2 Receiver

Error #1: The total system losses are always zero since the variable TPLDB is set to the total losses in dB, but then instead of converting this value from dB to a ratio (LTOTAL), the uninitialized value (assumed zero) of LTOTAL is always converted from dB to a ratio.

Documentation Reference: SUM, Appendix E, PPLOSS-1, block (2).

Implications For Model Use: No system losses are ever modeled for the AI radar.

Projected Corrections or Changes: Calculate the variable LTOTAL by converting the variable TPLDB from dB to a ratio (PPLOSS-1, block (2)).

2.4.3 Antenna

Error #1: Immediately before calling the routine UPDAT1 to update the antenna line-of-sight direction cosine matrix (CRFMB), the current value of this direction cosine matrix is set equal to the matrix MTX1. The matrix MTX1 is then operated upon to obtain an updated CRFMB matrix. However, since the matrix MTX1 is never initialized (and assuming all its elements are equal to zero), the elements of the matrix CRFMB will always be zero.

Documentation Reference: SUM, Appendix E, ANTMOV-2, block (3).

Implications For Model Use: Motion of AI radar antenna will not be possible.

Projected Corrections or Changes: The matrix MTX1 should be set to the matrix CRFMB before calling the routine UPDAT1 (i.e. the opposite to the current implementation). The whole of the AI radar modeling is due to be revisited.

III MISSILE

1.2 Movement

1.2.2 Aerodynamics/Kinematics

Error #1: When the missile aerodynamic data tables are read by the routine ATINPT, there is an error in the logic for processing the point-mass data. This involves a misplaced “ENDIF” statement and a misspelled array name.

Documentation Reference: SUM, Appendix E, ATINPT-3, block (5), block (6) and block (7).

Implications For Model Use: This function will not operate correctly as coded, but implications not evaluated.

Projected Corrections or Changes: Insert an "ENDIF" immediately after the last line of block (5) (i.e. before the "ELSE" that starts block (6)). Change the array CYTMDM to CYTGDM in the sixth line of block (6). Delete the "ENDIF" on the third line of block (7).

Error #2: In the calculation of the missile position relative to the launch aircraft, the calculation of the z-position is assigned to the y-position (MSRNGY), overwriting the previously calculated value, and the z-position (MSRNGZ) is never assigned.

Documentation Reference: SUM, Appendix E, MSINIT-4, block (1).

Implications For Model Use: None for current TRAP structure. The erroneous value only exists until it is recalculated in the routine GEOM, before it is used anywhere. This would only be a problem if code were written that saved the value calculated here for future use.

Projected Corrections or Changes: Rectified in TRAP 4.0.

Error #3: (At missile launch) The cross-range rate is calculated by multiplying the missile velocity by the sine of the flight-path angle in azimuth (GAMMAH) only.

Documentation Reference: SUM, Appendix E, LNCHML-11, block (3).

Implications For Model Use: The calculated cross-range rate will be in error unless the flight-path angle in pitch (GAMMA) is zero.

Projected Corrections or Changes: Multiply the existing expression for cross-range rate by the cosine of the flight-path angle in pitch (GAMMA). Corrected in TRAP 4.0.

Error #4: The maximum lateral acceleration available to the missile normal to the flight-path is calculated using the maximum trimmed AOA for calculating the normal force coefficient, but uses the axial force coefficient at the current AOA, not the value at the maximum trimmed AOA.

Documentation Reference: SUM, Appendix E, AEROM-5 and 6, block (9).

Implications For Model Use: Error in maximum 'g' available (value calculated will be too high). This value is used to trigger one of the termination conditions (available lateral acceleration less than user specified value), so it will affect whether some flyouts are scored as successes or failures (i.e. some flights will continue when they should have been terminated based on this criterion).

Projected Corrections or Changes: Use the drag coefficient at the maximum trim AOA (SUM, Appendix E, AEROM-6, block (9)).

Error #5: Linear yaw-plane aerodynamics (Trimmed Forces (Point-mass)) - The calculation of the side force coefficient (CYBETA) per unit angle-of-sideslip as a function of the AOA and Mach number, has the order of the arguments reversed for the AOA and Mach number in the call to the table look-up routine (TAB2DD).

Documentation Reference: SUM, Appendix E, AEROPM-10, block (7).

Implications For Model Use: At best a wrong value will be returned for the side force coefficient (CYBETA). In some instances (e.g. AOA (in degrees), greater than the maximum Mach number in the table) the current implementation will give an out-of-bounds error on the table look-up and program execution will be terminated.

Projected Corrections or Changes: Switch the order of the AOA and Mach number in the argument list for the call to the routine TAB2DD (SUM, Appendix E, AEROPM-10, block (7)).

<u>Error #6</u>: The past values of variables updated in the routine MSTATE should be set to the current value of the variable before the variable is updated. Currently, the past values of AOA (OALPHA), sideslip (OBETA, sine definition and OBETAT, tangent definition), and flight-path roll angle (OPHIVM) are set to the new value just prior to exiting the routine.

Documentation Reference: SUM, Appendix E, MSTATE-7 block (14).

Implications For Model Use: The setting of past values of variables to the new values, just prior to exiting MSTATE, means that the only place in the code that there is a difference between the current and past values of these variables is in the routine MSTATE. However, other parts of the code rely on their being a difference between the current and past values and these will not function correctly (e.g. AOA autopilot).

Projected Corrections or Changes: Rectified in TRAP 4.0 for the variables indicated here.

6.0 DME

<u>6.1 Guidance</u>

<u>Error #1</u>: The guidance scheme for constant flight-path angle in azimuth contains several errors. When calculating the desired cross-range position in reference axes, the missile cross-range position at launch is subtracted (rather than added). When calculating the cross-range error in reference axes, the missile cross-range position relative to the initial missile flight-path is subtracted from the desired value in reference axes (rather than subtracting the missile cross-range position in reference axes). The desired cross-range rate in reference axes is calculated by multiplying the missile cross-range velocity in reference axes by the tangent of the desired flight-path angle in azimuth (rather than multiplying the missile downrange velocity in reference axes by the tangent of the desired flight path angle in azimuth).

Documentation Reference: SUM, Appendix E, CONANY-3, blocks (1), (2) and (4).

Implications For Model Use: Will not produce desired flight-path.

Projected Corrections or Changes: Requires several modifications (SUM, Appendix E, CONANY-3, blocks (1), (2) and (4)).

6.2 Autopilot

<u>Error #1</u>: The expression for the combined acceleration feedback uses the wrong sign for the forward accelerometer feedback (applies to both pitch and yaw channels).

Documentation Reference: SUM, Appendix E, ACELFP-4, block (3) and ACELFY-4, block (3).

Implications For Model Use: Autopilot will fail (unstable) as coded.

Projected Corrections or Changes: Change the sign of the forward accelerometer feedback.

Error #2: There are errors in the way that the equivalent trim control surface deflection is calculated for the point-mass missile.

Documentation Reference: SUM, Appendix E, AERDRG-7, block (1), AERDRG-7 and 8, block (7) and AERDRG-9, block (8).

Implications For Model Use: Error in calculated axial force in some circumstances.

Projected Corrections or Changes: Implement corrections outlined in SUM, Appendix E, AERDRG-7, block(1), AERDRG-7 and 8, block (7) and AERDRG-9, block (8).

Error #3: The setting of the past values of AOA (OALPHA) and sideslip (OBETA) in the AOA autopilot routines is inappropriate. This function is performed in the state update routine (MSTATE). However, the way that the past values are set in the routine MSTATE (the past values are set to the new values on exit from the routine, rather than to the current values on entry into the routine, means that there is no difference between current and past values when entering this autopilot. The setting of the second past values (O2ALPH and O2BETA) does not currently create a problem, as this autopilot is the only place that these second past values are used, however, these values should also be set in MSTATE. Note that the sideslip autopilot should be using the tangent definition of sideslip (BETAT and OBETAT) instead of the sine definition (BETA and OBETA) - see below.

Documentation Reference: SUM, Appendix E, ANGLCP-2, block (5) and ANGLCY-2, block (5).

Implications For Model Use: Due to the way in which the past values of AOA and sideslip are currently set in the routine MSTATE (see missile state update), there is no difference between the current and past values when entering this autopilot and it does not function correctly.

Projected Corrections or Changes: In TRAP 4.0, the setting of the first past values in these autopilot routines has been deleted and the setting of the first past values in the routine MSTATE has been corrected. The setting of the second past values still need to be moved to MSTATE.

Error #4: The tangent definition of the sideslip angle (BETAT, OBETAT) should be used in the sideslip autopilot not the sine definition (BETA, OBETA). In addition, the sign of the raw sideslip angle error should be changed because a positive error requires a negative rate demand.

Documentation Reference: SUM, Appendix E, ANGLCY-3, block (2) and block (3).

Implications For Model Use: If the AOA is small, the effect of using the sine definition of sideslip compared to the tangent definition will be small. However, the use of the wrong sign of the sideslip error angle will cause this autopilot to fail (unstable) as coded.

Projected Corrections or Changes: Should be rectified in TRAP 4.0.

Error #5: The roll autopilot for the 6-DOF missile is used to maintain the body roll angle at zero. However, the feedback is provided by the body roll rate (rather than the rate-of-change of body roll angle).

Documentation Reference: SUM, Appendix E, ROLLAP-1, block (1).

Implications For Model Use: The current implementation can lead to instabilities in roll.

Projected Corrections or Changes: Replace the roll rate feedback with rate-of-change of body roll angle feedback. Rectified in TRAP 4.0.

Error #6: The demanded control deflections in pitch, yaw and roll for the ‘x’-configuration are not limited before being resolved into demands for the individual actuators.

Documentation Reference: SUM, Appendix E, ACTUAT-4, block (10).

Implications For Model Use: When the output of the individual actuators is subsequently limited and resolved back to pitch, yaw and roll channels, it is possible for a large demand in one of the channels to cause zero effective response in the other two channels.

Projected Corrections or Changes: Rectified in TRAP 4.0.

Error #7: For the ‘x’-configuration, the outputs of the individual actuators are not limited before saving them as past values for use by the Tustin integrators at the next time step.

Documentation Reference: SUM, Appendix E, ACTUAT-5, block (11).

Implications For Model Use: Physically unreasonable values can be carried through as past values and the Tustin integrators will not behave correctly.

Projected Corrections or Changes: Rectified in TRAP 4.0.

Error #8: Torque-balance control autopilot - The conversion of the actuator demands from torque demands to angular demands has a mismatch of units.

Documentation Reference: SUM, Appendix E, ACTUAT-7, block (3).

Implications For Model Use: This function will not operate correctly as coded.

Projected Corrections or Changes: The input torques should be converted into coefficient form, and the appropriate data table should be examined to determine the control deflections that will produce the required torques (SUM, Appendix E, ACTUAT-7, block (3)).

Error #9: Synthetic stability control autopilot - When the individual control surface deflections are converted to equivalent pitch and yaw deflections for use by the aerodynamics routines, the expressions are erroneously multiplied by a factor of SIN45. This is not necessary since it is the actual control surface deflections that should be summed not ‘resolved’ values.

Documentation Reference: SUM, Appendix E, ACTUAT-11, block (14).

Implications For Model Use: The actuator gain is effectively reduced to 70% of the input value.

Projected Corrections or Changes: The factor SIN45 should be removed from the calculation.

GENERAL

Coordinate Transformations

Error #1: The routine ROTATE is used to transform a vector through a specified number of rotations from one set of axes to another. However, if more than one rotation is performed, the output vector is simply the input vector transformed through the final rotation of the specified sequence (the results of any preceding rotations are not carried through the calculation).

Documentation Reference: SUM, Appendix E, ROTATE-3, block (1).

Implications For Model Use: This routine is only called from the routine PKL (pseudo kinematic link guidance), thus the effects are limited to missiles employing this type of guidance.

Projected Corrections or Changes: At the end of each rotation, overwrite the input vector with the result of that rotation (SUM, Appendix E, ROTATE-3, block (1)).

Launch Zone Generation

Error #1: Binary search - The variable BNDIN (current value of successful minimum range) is never initialized.

Documentation Reference: SUM, Appendix E, BFNDRNG-4, block (6) and BFNDRNG-5, block (8).

Implications For Model Use: This means that one of the conditions for ending the search for the inner launch zone boundary will never be met.

Projected Corrections or Changes: Initialize the variable BNDIN to an appropriate value. However, the launch zone generation is being completely reformulated for TRAP 4.0.

Error #2: Binary search - The criterion placed on the time of flight for the inner boundary in block (8) of the routine BFNDRNG is not consistent with that used in block (6) of the routine.

Documentation Reference: SUM, Appendix E, BFNDRNG-5, block (8).

Implications For Model Use: A successful flyout can occur (based on block (6)) which lies between 99.9% and 100% of the minimum missile flight time (MMNTIM), which will not properly terminate the search for the minimum boundary.

Projected Corrections or Changes: Change the criterion in block (8) which stops the search for the minimum range to be TMINRG ≥ 0.999*MMNTIM. However, the launch zone generation is being completely reformulated for TRAP 4.0.

<u>Error #3</u>: Binary and smart searches - When a boundary point is found, the intercept is rerun with a launch range multiplied by the parameter RFAC. If both inner and outer boundaries are being generated, the factor is applied in the same manner to both boundaries; i.e. if RFAC is less than 1.0, an attempt will be made to perform an intercept at less than the minimum launch range, and if RFAC is greater than 1.0, an attempt will be made to perform an intercept at more than the maximum launch range.

Documentation Reference: SUM, Appendix E, BNLARB-8, block (14) and LARBND-8, block (14).

Implications For Model Use: If searching for both inner and outer boundaries with RFAC not equal to 1.0, then when boundary points are rerun either the inner or outer boundary will produce failures.

Projected Corrections or Changes: Define how RFAC should be used and modify code accordingly (SUM, Appendix E, BNLARB-8, block (14) and LARBND-8, block (14)). However, the launch zone generation is being completely reformulated for TRAP 4.0.

<u>Error #4</u>: Binary and smart searches - If a vertical launch zone is being generated, when the routines BFNDTAN (binary search) or FNDTAN (smart search) are called, the current condition is sent in the argument list as a line-of-sight angle in pitch (THETRO), but the previous condition exists as an altitude (PRVANG) in the common block “LZNCMN”.

Documentation Reference: SUM, Appendix E, BNLARB-9 block (16) and LARBND-9, block (16).

Implications For Model Use: Unknown. The routines BFNDTAN and FNDTAN expect that both the current and previous conditions will be in the same units, and are unlikely.

Projected Corrections or Changes: Send everything to the routines BFNDTAN and FNDTAN as an altitude for vertical launch zones (SUM, Appendix E, BNLARB-9, block (14) and LARBND-9, block (16)). However, the launch zone generation is being completely reformulated for TRAP 4.0.

<u>Error #5</u>: Binary search - In the routine BNSRCH, which determines what shot should be taken next during the binary search, there are several inconsistencies when searching for the inner boundary.

Documentation Reference: SUM, Appendix E, BNSRCH-4 to 6, block (3).

Implications For Model Use: The inner boundary will not be correctly determined in some instances.

Projected Corrections or Changes: Several modifications are needed (SUM, Appendix E, BNSRCH-5 and 6, block (3). However, the launch zone generation is being completely reformulated for TRAP 4.0.

<u>Error #6</u>: Initial conditions for flyout - In determining the allowable line-of-sight angle in the vertical plane, there are calculations that equate angles that are in different units, and which do not take account of whether the launch aircraft is climbing or descending. In addition, the calculations are only appropriate for a vertical launch zone, but can overwrite earlier calculations appropriate to a horizontal launch zone.

Documentation Reference: SUM, Appendix E, BOUND-4, block (6).

Implications For Model Use: The initial conditions for some launch attempts will be inappropriate.

Projected Corrections or Changes: Several modifications are needed (SUM, Appendix E, BOUND-4, block (6)). However, the launch zone generation is being completely reformulated for TRAP 4.0.

<u>Error #7</u>: Smart search - The minimum value for the inner boundary limit calculated in the routine LARBND is 100.0 m but this will be overwritten in the routine FNDRNG to a value of 300.0 m.

Documentation Reference: SUM, Appendix E, LARBND-5, block (3) and FNDRNG-2, block (2).

Implications For Model Use: The minimum launch range will never be less than 300.0 m for the smart search.

Projected Corrections or Changes: Determine which value (100.0 m or 300.0 m) should stand and delete the other calculation. However, the launch zone generation is being completely reformulated for TRAP 4.0.